TRACK,

A COMPLETE MANUAL OF

MAINTENANCE OF WAY,

ACCORDING TO THE LATEST AND BEST PRACTICE ON LEADING
AMERICAN RAILROADS.

BY

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INTRODUCTION.

In the rapid and extraordinary growth of railroad construction, within the last sixty years, the improvements made in the road-bed have been many and very marked in degree, and the proper maintenance of this important department has always been an interesting study.

Within the last fifteen years, however, the introduction of steel rails has practically worked a complete revolution in the construction and care of railways, and the few really good works which treated of iron rails and their details are now out of date in many features and valueless as guides to the trackmen.

In the following pages the author has endeavored to put into a compact, simple form the latest practice in the maintenance of track as deduced from the accepted methods of the prominent trunk lines of railway in the United States.

The purpose of this volume is to describe the materials used in the construction and maintenance of the road-bed; the tools handled by the trackmen; the appliances and structures connected with the track and in the charge of the track department, and to fully discuss the most profitable manner of doing work.

It is intended to be essentially a "practical" treatise; but one fully recognizing the value of scientific work and simply reducing these scientific methods to their most thoroughly practical form. With this end in view, mathematics have been avoided as much as possible, and likewise abstruse technical problems which have been fully discussed by other authors.

One of the valuable features of this work will be its details of illustration and description. The information given is intended to be precise, accurate and to the point; and the illustrations are all made from actual working drawings, and are given with such dimensions as are considered requisite.

Wherever possible the cost is given, in day's labor, of the construction of an article, or the doing of a certain piece of work; and when essential, a bill of material has been appended. This feature of cost has been very generally neglected, and its insertion here, it is believed, will be found of material assistance to superintendents and others who have not had an opportunity of personally gaining the information necessary for estimating on new work or checking the cost of work done by their assistants. As prices of material and the wages of men are constantly fluctuating, the time necessary to accomplish a certain piece of work has been alone given, as obtained in the author's experience in work done under average conditions.

NEW YORK, MARCH, 1886. W. B. P., JR.

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SECTION LENGTH.

THE track of a railroad for the purposes of maintenance is divided into sections of greater or less extent, each section being taken care of by a foreman and a gang of men.

The proper length of a section depends upon several conditions; amount of traffic, kind of ballast, condition of road-bed, amount of outside work, such as switches, etc., and excellence of track expected. For a single track, lengths ordinarily vary from four to seven miles, with extreme cases on very poor lines, of eight and ten; but four and a half or five miles can be adopted as a fair standard for average condition.

On double track, lengths vary from three to five miles, with three and a half or four as equivalent to five on single track.

The amount of work is not quite twice as great on a double line. Ditching, cleaning up, cutting grass, and such work are about the same in either case: but the double line operates in favor of the men, inasmuch that they always know from which direction to look for trains, and can do their work and run their handcar or grampus with corresponding safety.

FORCE REQUIRED.

What constitutes the proper allowance of force, depends so largely upon the financial condition of the company, that no rule can be laid down in a work like this. It is not economy, although it is sometimes necessary, to reduce the force below certain limits, to the injury of rolling stock, discomfort of passengers and increased possibility of accident. On the great trunk lines large section gangs, and "extra" or "floating" gangs in addition, must be employed to keep the road in a condition commensurate with the traffic. But in general, with one man per mile of single track, equivalent to three-fourths man per mile of track of double line, exclusive of foreman and watchman, a very good track indeed can be maintained, unless the materials are very poor. It is best, however, not to keep a uniform number of men throughout the year, but to increase and decrease according to the demands of work. If rails, ballast and ties, are in good condition, and the locality such as not to require a large force in winter to fight snow, the number of men in a gang can be reduced, during the season when ground is frozen, to very low limits, or just enough to do picking, cleaning and occasional shimming. Thus, with permission to take on more men on an emergency (and in winter extra men can always be had), a foreman and two or three men and two track walkers can accomplish a great deal. As soon as spring comes, increase the gang to the full extent that a foreman can handle, say ten to fifteen, so as to get the

ties in, joints raised, and heavy work done before early harvest time calls off laborers. The force can then be cut down to one man per mile, or some such limit, and when autumn arrives, the track will be in excellent condition, so that a further reduction can again be safely made to meet the winter allowance. The above is the most economical way to do the work, as labor is employed at the season when abundant, and when it can accomplish most. To allow track to run down in summer on account of inadequate force, means that a large number of men must be retained in winter, when, with the short days and inclement weather, the minimum only can be done with a day's labor to block and shim in order to temporarily make good that which was neglected in the proper time. Likewise, the increased cost of maintenance with old rails and poor ballast would more than pay interest on the investment for good materials. Where large yards occur, either the section limit must be reduced or the force increased, or both; while if a yard is very large, it is then best to have several gangs, in charge of assistant foremen who report to one general foreman.

TRACKWALKERS.

To this section force is to be added one trackwalker who should walk the section at least once a day, and on roads doing a night business, a second trackwalker should patrol the section at night. During the summer, if no washouts or other dangers are to be apprehended, the former can safely be allowed, after having walked the track and performed his regular duties in the forenoon, to join the section gang in the afternoon. But in the seasons when accidents are most liable to occur, he should be kept constantly patrolling his section, and at such times, if not all the time, a night walker should also be put on. If there are particularly dangerous spots, such as sliding banks, cuts through loose rock, etc., special watchmen should be detailed to these places. Too much care cannot be given to safely guarding the track.

The day trackwalker should be provided with a wrench, a light hammer having one end edge pointed, and a flag. Besides merely walking over the track he should tighten loose bolts, drive down spikes that are working up, and carefully examine on each trip every bridge to detect any sign of fire, and also inspect all switch connections and frogs. During warm weather, if the switches are of the "stub" pattern, he should throw them each day, and if found too tight, should so report. In winter he should keep snow and ice from packing hard about switches, frogs, guard rails and crossings. In fact, the position of trackwalker is one of more than ordinary importance and should be entrusted only to a careful and reliable man.

The night trackwalker is expected only to walk the section and see that everything is safe. He should be provided with a lantern and torpedoes. As a rule, the times of starting on their trips can be so arranged as to have the trackwalkers cover their sections immediately in advance of the principal trains.

TOOLS.

Each section force should have a complement of good tools, full enough to supply every man in the gang, and also some in addition of such kinds as need occasionally to be sent to the shop for repairs or dressing. Besides these, there should be kept on hand at headquarters an extra stock from which to equip a sudden necessary increase of force at a time of flood, washout, wreck, or similar emergency. For a gang composed of foreman, two track walkers and six men, the following list will be sufficient for all ordinary cases :

List of Tools.

Hammers:	Four Spiking Mauls,	*Shovels:*	One Long-handled Shovel,
	Six Ballast Hammers,*		Six Common Shovels,
	One Nail Hammer,		Six Scoops.
	One Trackwalker's,	*Axes:*	One Common Axe,
	Two Sledges.		Two Adzes,
Bars:	Eight Tamping Bars,		Two Hand Axes or Hatchets.
	Three Lining Bars,	*Wrenches:*	Six Track Wrenches,
	Three Pinch Bars,		One Trackwalker's Wrench,
	One Heavy Pinch Bar,		One Monkey Wrench.
	Three Claw Bars.	*Signals:*	Four Red Flags,
Picks:	Eight Common Picks,		Five White Lanterns,
	Six Tamping Picks*.		Two Red Lanterns,
	Three Grub Hoes.		Eight Torpedoes.

Miscellaneous:

One Hand Car,	One Brace, 2 Bits, (3-4 inch),
One Grampus, or Push Car,	One Water Pail and Dipper,
One Track Jack or Lever,	One Tape Line (50 feet),
Two Track Gauges,	One Large Oil Can,
Three Rail Tongs,	One Oiler,
Twelve Chisels,	One Spirit Level,
One Hand Saw,	One Level Board,
One Cross-cut Saw,	Two Brooms,
One Bush Hook,	Three Wheelbarrows,
Six Scythes and Snaths,	One Grindstone,
Ratchet Drill and 3 Bits (1 in.),	2 tubs, 3 White-wash Brushes.

Tools marked * are needed only with stone ballast. If there is a section where rocks are liable to fall, it should be equipped with tools to facilitate their removal, consisting of rock drills, stone wedges, blasting powder and fuse.

Also, if there are special watchmen to guard dangerous rock cuts, sliding banks, or the like, each man should be furnished with: one wheelbarrow, one pick, one shovel, one ballast hammer, two flags, and six torpedoes. Besides the tools named above there should be kept on hand at the supervisor's or road-master's headquarters one or more rail benders or "jim-crows."

Ordinarily the regular tools, like picks and bars, are made in the company's blacksmith shop.

Convenient sizes and weights to make the regular tools are here given; to which is added in each case the necessary labor required in their manufacture, by stating how many a blacksmith and helper can make in an average day's work of ten hours, that is, the daily capacity of each fire. The exact cost in dollars of each tool can thus be readily found when the value of the raw material, and the rate paid for labor is known.

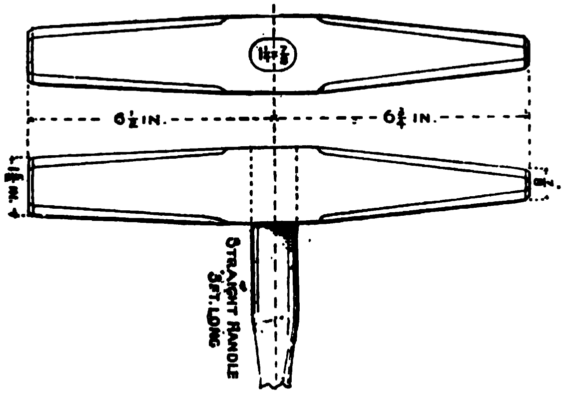


FIG 1.—MAUL—Weight 10 lbs.

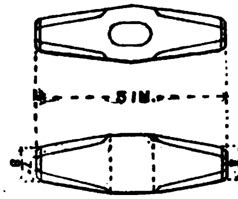


FIG. 2.—BALLAST HAMMER—Weight 3½ lbs.

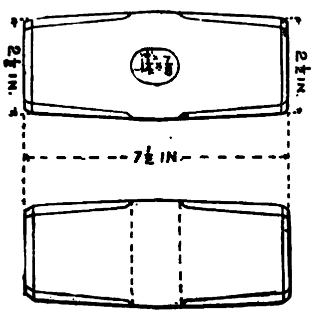


FIG. 3.—SLEDGE—Weight 12 to 13 lbs

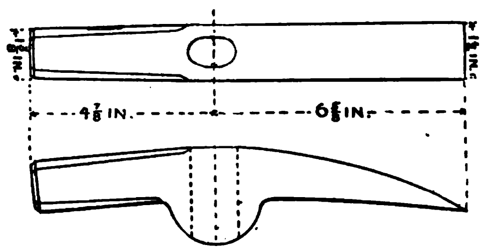


FIG. 4.—TRACK WALKER'S HAMMER—Weight 4 lbs.

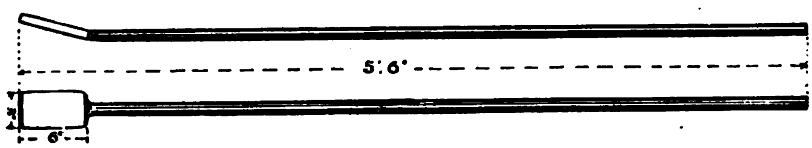


FIG. 5.—TAMPING BAR. Weight 13 lbs,

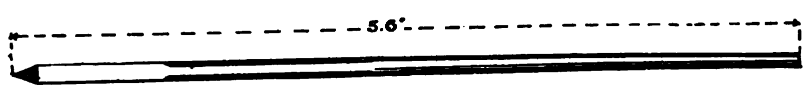


FIG. 6.—LINING BAR. Weight 30 lbs.

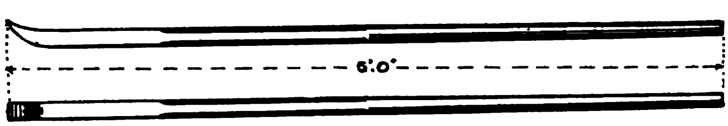


FIG. 7.—PINCH BAR. Weight 26 lbs

This question of cost of labor varies according to several conditions, such as rapidity of the workmen, facilities at hand for doing work, convenience of shop arrangements, and whether the tools are made of new material, or from the assortment of old junk, which is always collecting around a railroad blacksmith shop, such as bridge rods, broken points from cast frogs, old tools, etc., material which in every case can be utilized, and although it may take more labor to remodel the old, yet a general saving on the whole is effected. Figures, however, as given here, are taken from actual work and can be relied on as a safe guide.

Spike Mauls (Fig. 1) are made of 2 1-8 in. square iron with piece of cast steel welded on each end. Face, octagonal, 1 5-8 in. across and 6 1-2 in. from center of eye. Top, (small end) octagonal, 7-8 in. across and 6 3-4 in. from center of eye. Eye, punched oval, 1 1-4 in. × 7-8 in.; weight about 10 lbs. Ten can be made in one day. With usage the face gets rounded, when the maul needs to be sent to shop and be re-dressed.

Ballast Hammers (Fig. 2) are made of iron with a small piece of steel welded on each end, 1 1-2 in. square at center tapering off to 7-8 in., octagonal face at each end. Length when finished 5 in.; and weight about 3 lbs. Oval hole 1 1-8 in. × 3-4 in.; about fifteen can be made in one day.

Sledges (Fig. 3) are 7 1-2 in. long with 2 1-2 in. octagonal face on each end. Oval hole 1 1-4 in. × 7-8 in. punched in center. Weight about 12 or 13 lbs. From four to eight can be made in a day according as old or new material is used.

Track-Walker's Hammer (Fig. 4.) is made of 1 3-4 in. square iron drawn out to octagonal face at one end and to an adze edge 1 1-2 in. wide at the other, making total length 11 1-2 in. Both face and bit are of steel, eye oval 1 1-4 in. × 7-8 in. center being 4 7-8 in. from face. Weight 4 lbs.; about ten can be made in one day.

Tamping Bars. (Fig. 5). The end is made of iron 6 × 3 × 3-4 in. welded into a handle of 7-8 in. round iron, giving a length over all of 5 ft. 6 in. with weight about 13 lbs. The end is welded on at such an angle as will be convenient for a man to strike well under a tie. Twenty can be made in a day. They should be sent to shop for re-dressing before before getting much rounded.

Lining Bars. (Fig. 6). Lower end is made of 2 ft. 6 in. of 1 1-2 in. square iron to which is welded 18 in. of 1 3-8 in. round, and to this is added 18 in. of 1 1-8 in. round all nicely tapered together. For the point weld in a piece of steel, when finished to be 5 ft. 6 in. long and to weigh about 30 lbs. Make about eight in one day. The point should be "diamond point" or sharp. A bar with a straight "chisel" or flat point is of little or no use.

This bar is an extremely useful tool whose place cannot be filled by any other. With its sharp point it can be driven down firmly into the ballast, and thus obtain a good foothold as a fulcrum to throw the track when lining is to be done. Two men can take hold of one bar.

Pinch Bar (Fig. 7) is made of 2 ft. 6 in. of 1 3-8 in. square, 1 ft. 3 in. of 1 3-8 in. round, and 1 ft. 3 in. of 1 1-8 in. round, tapered and with steel end as in "lining bar." When finished to be 5 ft. long and to weigh about 26 lbs. Can make about

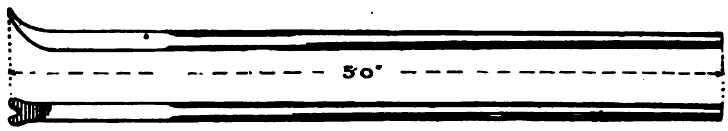


Fig. 8.—Claw Bar.—Weight 30 lbs

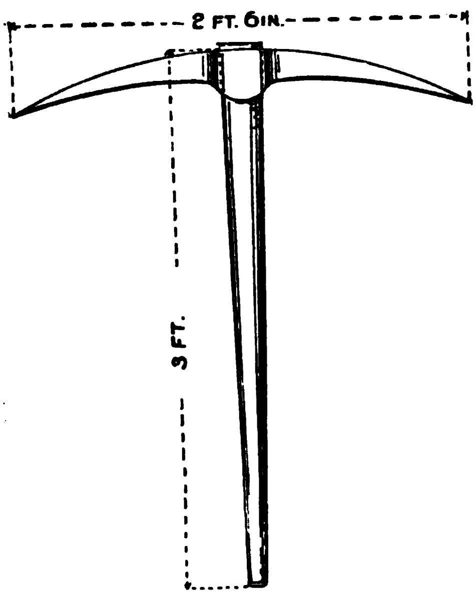


Fig. 9.—Pick—Weight 7 lbs.

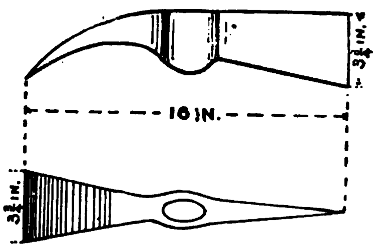


Fig. 10—Grub-hoe—Weight 5¼ lbs.

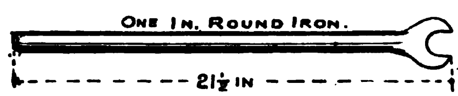


Fig. 11.—Wrench—Weight 5¼ lbs.

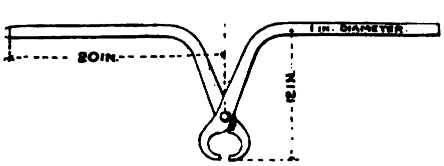


Fig. 13.—Rail Tongs—Weight 13 lbs.

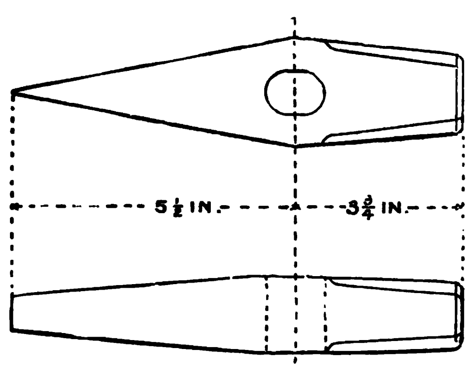


Fig. 12.—Chisel—Weight 4 lbs.

eight in a day. The point to be "chisel" point and slightly turned up so as to get a hold when prying. The use of this bar is to hold up a tie in place when being spiked, or it is handy in the continual requirement of a bar that can lift and pry up. The heavy bar as called for in the tool list is one of this type made of 3 ft. of 1 5-8 in. square, 2 ft. 6 in. of 1 3-8 in. round and 2 ft. 6 in: of 1 1-8 in. round. Length when finished 8 ft. and weight about 41 lbs. Such a bar is used in raising low joints or in hard lifting.

The Claw Bar (Fig. 8) commences with 2 ft. of 1 1-2 in. square with upset end and 3 in. of 2 in. square cast steel welded in for the claw. Then 18 in. of 1 3-8 in. round and 18 in. of 1 1-8 in. round. When done to be 5 ft. long and to weigh about 30 lbs. On account of care required, only three can be turned out in a day. The forming and shape of the claw needs great attention, and considerable skill to make perfect. The angle of the claw with the bar should be about 45°, which gives a convenient angle for a man to drive it under a spike head. Some bars have a long curve connecting claw with the bar so that the latter is about at right angles with the former. This is called in track parlance a "high-heeled" or "goose-neck" bar, and with it a spike can be drawn straight without putting a rest or "bait" under the heel. With this bar, the angle between claw and bar is so great that it cannot be struck under the spike head conveniently, and therefore trackmen sometimes object to it. The best arrangement, if much drawing is to be done, is to have both kinds, the straight-bar preceding and starting the spikes up, while the high-heeled bar follows, drawing them entirely. Two men can work faster, and with less injury to spikes this way, than one man with straight bar, and another accompanying him to hold "bait."

Picks. (Fig. 9.) The best pick is one with a solid cast steel eye which will not split with use. Such picks must be bought. If however it is necessary to make picks, they can be constructed as follows: two pieces of iron 1-2 in. × 2 in. × 12 in. with cast steel ends welded on, the two pieces welded together, and drawn out so that length over all is 2 ft. 6 in.; eye oval 2 × 3 in. and 2 1-2 in. deep. Weight about 7 lbs., and eight to ten can be produced in a day.

Tamping Picks are made in the same way as common picks with a piece 3-4 in × 3 in. welded on one end. All picks should be made of best refined iron.

Grub Hoes. (Fig. 10.) These are very useful tools in cutting roots and grubbing heavy sod, and the like, preparatory to new work; also handy in ditching and removing tough grass from the side of the track. One is made of 1-2 in. × 2 in. iron with an adze edge at each end, both steel shod. One of these edges is horizontal and the other perpendicular or in line with the handle so that it can be used as an axe. Length over all is 16 in. and length of cutting edge 3 1-4 in. Eye like a pick 2 in. × 3 in. × 2 1-2 in. deep. Weight 5 1-2 lbs. and five or six can be made in a day.

Wrench. (Fig. 11.) Extreme length 21 1-2 in., handle made of 1 in. round iron with steel jaws flat and 7-8 in. thick. Weight 5 1-2 pounds and daily out-put fifteen. The end of the handle is drawn out tapering to 1-2 in. so that it can be shoved through bolt holes in splice bars and rails in order to bring the holes opposite when putting them together. Wrenches made longer than this give a man such leverage that he can twist off the bolts without applying great force, a needless and expensive proceeding.

Chisels. (Fig. 12) are made of 1 1-2 in. square cast steel 6 1-2 in. long. Eye is punched in center and then one end tapered out for a cutting edge, the sides of which

should not be too lean or point will break. The distance from center of eye to bit is 5 1-2 in., and 3 1-4 in. to head, making total length finished 8 3-4 in. Weight about 4 lbs. Twenty-five to thirty can be made in a day. Great skill is required in giving the bit a good shape and especially a correct temper. If latter is too hard the chisels will break in use, and will dull if it is too soft.

A good chisel should cut three or four rails. In winter they are particularly apt to break, and therefore the first blows given them should be easy. It is even a good plan to warm them before using in very cold weather. The length for handle should be about 18 in., which is requisite for the man holding it to keep out of the striker's way. As regards cost of repairing dulled or broken chisels, sixty to seventy-five, according to condition, can be put in into shape in a day. If, however, they are only slightly dulled the track-men can generally sharpen them on their grindstone.

Rail Tongs (Fig. 13) are made of two pieces of 1 in. round iron 2 ft. 6 in long with a small piece welded on the end to make the jaw. Where they are hinged they are drawn out to 1 1-2 in. × 1-2 in. and held by a 1-2 in. bolt. Jaws 1 1-2 in × 3-4 in. thick. Weight 13 lbs. Six to seven can be made in a day.

Such are the tools made in the blacksmith's shop. The principal features of the others that deserve mention are here noted.

Long-handled Shovels have a straight handle about 4 ft. long, and are used in digging post holes.

Scoops are large full shovels for handling cinders, snow, etc.

Hand-cars can be made at company shops, but it is about as cheap to buy them from some of the large factories. Fig. 14 represents the Sheffield car with wooden wheels, weighing all told about 500 lbs., as light a car as is made and yet perfectly strong. It has been adopted as the standard of the N. Y. W. S. & B. R. R. and other roads. Such a car can carry 10 or 12 men. Hand-cars should be

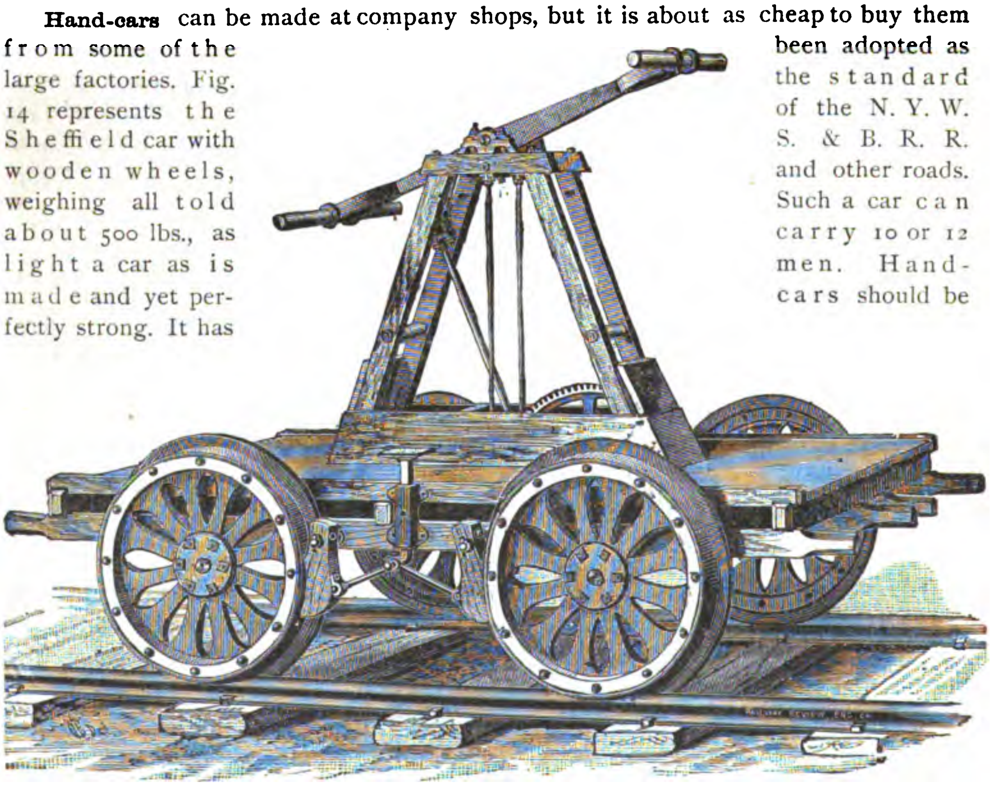


FIG. 14. HAND-CAR.

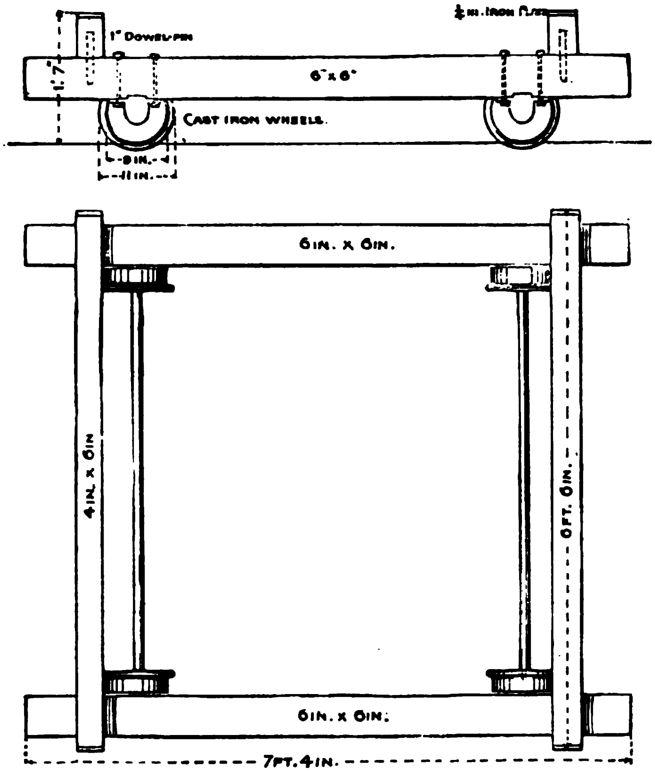


Fig. 15. Grampus.

well lubricated on all bearing surfaces, enough to answer the purpose but not a wasteful amount to run down and catch dust and grit. Better oil "little and often." They should be kept in good condition and repair, that is, perfect running order. Otherwise by working hard and running slow they can be made very expensive affairs

A good form of **Grampus** is shown in detail in Fig's. 15 and 16. The side sills are held on the journals by the boxes (shown in Fig. 16) and the cross caps held to them by iron dowels. As each piece is thus separate, the car can be quickly taken apart and easily shipped, and with its little wheels set low it is convenient for men to load and unload. If it is not intended to carry extra heavy weights, the scantling of the side bars can be reduced to 5 × 6 in. or 4 × 6 in.

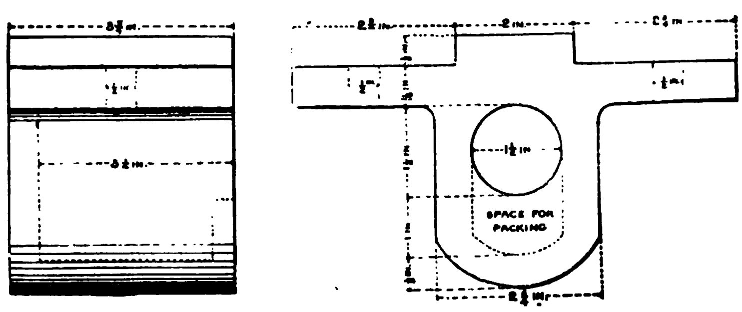


Fig. 16. Details of Box of Grampus.

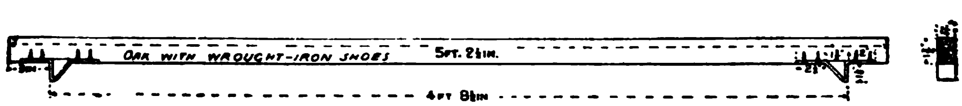


Fig. 17. Track Gauge.

Track Gauges. Fig. 17—In order not to be affected by temperature, but more especially to prevent their being bent, track gauges should be made of wood in preference to iron, best of 1 1-2 in. × 2 in. well seasoned ash with cast iron lugs screwed on at proper distance for gauge.

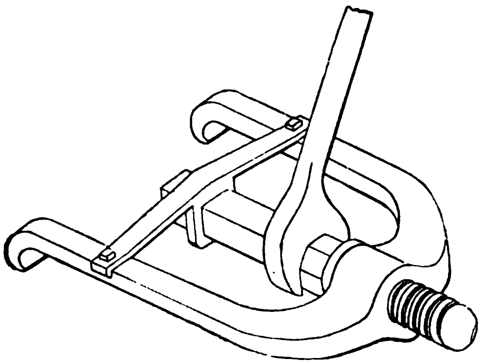


FIG. 18—RAIL BENDER.

The simplest form of **Rail-Bender** is shown in Fig. 18. The two arms are hooked either over the head of the rail, or under the base, according to the style of machine and pressure applied through the screw. Patented devices in great variety also exist, deriving their power from eccentrics, hydraulic motors and other mechanical appliances.

Track Levers, Fig. 19 are used when track is being raised considerably, several men being able to bear down on them at one time. A ring is provided at one end to facilitate carrying. They are best made of oak, and in length about 9 to 10 ft. They are shod with 5 1-2 in. iron turned up as shown in the figure.

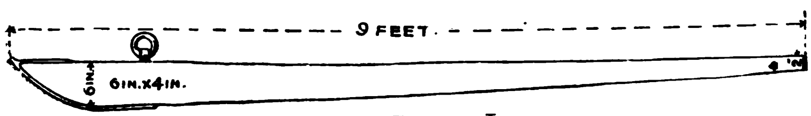


FIG. 19.—RAISING LEVER.

The lever, however, is the old tool of which the modern substitute is the **Track-Jack.** Like the rail bender there are many varieties, according as the principle of operation is the screw, rack and pinion, hydraulics, friction clutches, or other mechanical devices. Fig. 20 gives the usual general appearance of a track-jack, although in Fig. 21 is shown the **Fisher-Jack** which lies down under the rail entirely out of the way of trains. There is no tool more useful and labor-saving than a good track-jack. The aid of each one to a section is equal to the labor of one man continuously, and in yards it is fully equivalent to two men. One man with a jack can raise the rail quicker, easier and better than three or four men with a lever, and when raised, the jack automatically holds the rail quite steady and permits the whole force to be working. The lever, on the contrary requires several men to work it, raises the track by jerks, and is difficult to adjust ac-

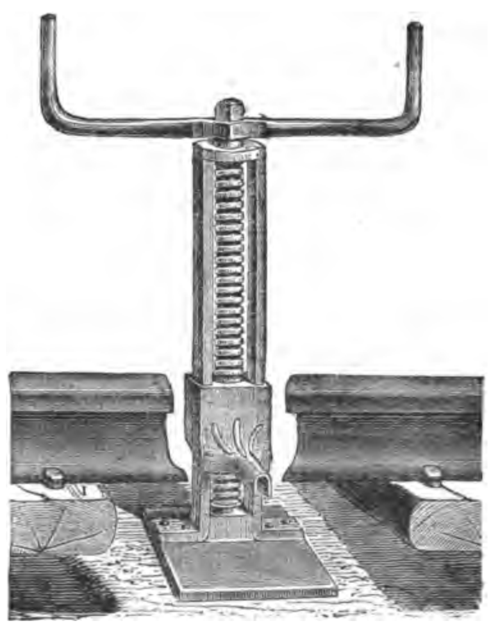


FIG. 20.—LIFTING-JACK.

curately, and even after proper raise is obtained, one man at least must hold it until the ties are tamped, and sometimes he will let it slip slightly in spite of all possible care.

Fig. 21.—Fisher-Jack.

Scythes are of several kinds. There is the common " grass scythe " which is too light for railroad work. Therefore, a slightly heavier form is made called the R. R. scythe" which can be mounted on the ordinary snath, or else the brush snath which has not quite so much curve. This scythe is used in cutting the ordinary coarse grass and light weeds.

Slightly heavier again is the " bramble scythe" to cut heavier weeds and brambles; while to cut brush and young bushes we have a shorter, stouter scythe called the "brush scythes." Both of these latter should be mounted on the brush snath. Then to cut bushes, there is the "bush hook." (Fig. 22,) a stout hook mounted on an ordinary axe helve. The different varieties are severally needed according to kind of herbage growing on the right-of-way. But ordinarily a set of "R. R. scythes" and "brush scythes," with a bush hook, is the most convenient equipment.

Fig. 22.
Bush Hook.

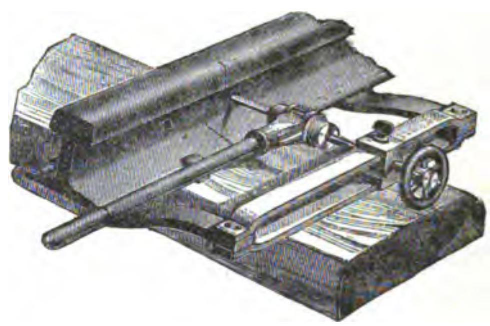


Fig. 23. Ratchet-Drills.

Ratchet Drills are used to bore holes in the rails. The best forms are covered by patents, and are supplied with automatic feed, so that one man can operate them. A good sample is shown in Fig. 23, by which any hole can be drilled, or if necessary, all four at one setting of the clamp. This clamp should be of such form as to grip the foot and not the head of the rail, in order not to be in the way of passing trains.

Level Board (Fig. 24), is 6 × 1 in. by 5 ft. 5 in. long, with a cast iron slide at one end, as shown in detail in Fig. 25. The plate A slides on plate B, but can be held at any point by tightening the

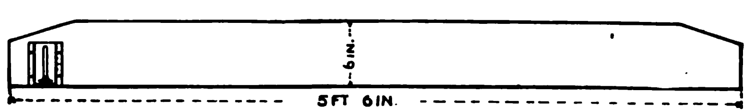


Fig. 24.—Level Board.

thumb screw, thus allowing one end of the board to be raised any exact amount above the other. By marking on the edge of the plate B a scale of inches this dif-

ference in elevation can be measured accurately and quickly. The bottom of plate A is widened 1-3 inch to give better footing. In order to determine when the board is horizontal, a spirit level is laid on the top edge which must therefore be made exactly parallel to the lower. This board is vastly superior in convenience to the ordinary level board with notches cut in one end.

One word upon two points worthy of a passing notice before leaving this subject of tools. Unless it is an increase, new tools should never be issued to a section until those worn out are returned, or a proper excuse offered for their non-appearance. By enforcing this simple rule carelessness in handling tools can be prevented with corresponding economy as the result.

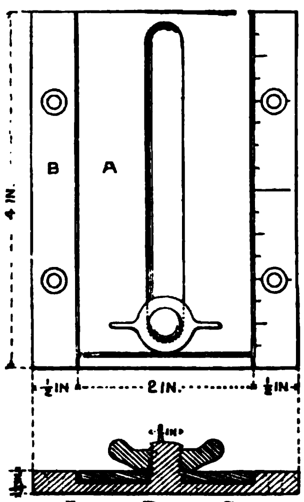


FIG. 25.—LEVEL BOARD SCALE.

Secondly, some organized system should be adopted as to the method of sending repaired tools back and forth between section and shop. Generally the foreman ties a tag to the bundle and lets it go. Often this tag gets wet and the address is obliterated or else it gets caught and is torn off, in which events the tools are either held at the shop, or else fall into the hands of some other gang, while the foreman to whom they belong worries and scolds at the delay. An easy plan is to proceed as follows: have some brass discs like baggage checks made; on one side stamp the number of the section and the name of the place as shown in Fig. 26; on the other side stamp the address of the shop; through the slot at one side attach a strap; when the check is to be fastened to a bundle slip the strap through the slot at the other side, and across the face bearing the address *from* which the tools are being sent.

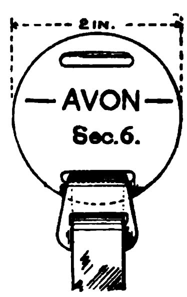


FIG. 26.
TOOL CHECK.

The address to which they are to go is thus left plain. Then attach as an ordinary baggage check. In case the same shop supplies several divisions, the checks of each division can be made of a different form so as to distinguish them. As a further guide each tool should be stamped with the section number to which it belongs.

CHAPTER II.

BALLAST—TIES—METAL TIES—PRESERVED TIES—DRAINAGE—CROSS SECTION SINGLE TRACK ROAD BED—CROSS DRAINS—CROSS SECTION DOUBLE TRACK ROAD BED.

BALLAST.

In construction the road bed is finished to a "sub grade," which is generally about one foot below "grade" or the bottom of the ties. The material which is used to fill up between the subgrade and grade is called ballast; it should be a substance which will not retain moisture about the ties and through which water can run freely; of such consistency as can be packed solidly under the ties and maintain this solidity under the hammering action of traffic and the softening effect of water; not liable to crumble and so make dust, and yet withal be economical. The materials most generally used for ballasting are: broken stone, furnace slag, burnt clay, gravel, cinders and mud.

Broken stone best fills the requirements of a perfect ballast. Its advantages are: (1) perfect drainage: (2) firm, even and permanent track; (3) will not freeze solid like gravel, unless a sudden frost follows a thaw or rain; (4) does not heave in cold weather; (5) can be worked in wet as well as in dry weather; (6) increased life to the tie; (7) freedom from dust. The best stone for ballast is trap or granite. Limestone, some varieties of sandstone, in fact, any stone that breaks uniformly in all directions and does not crumble easily, will answer tolerably well. For use it should be broken evenly, and of such size that it can pass in any way through a 1 1-2 inch ring. If stones are too large the track will work out of line.

Stone is most economically broken by some form of rock crusher. If possible locate the source of supply considerably higher than the track, place the crusher midway so that the rock can be dropped into it; the broken stone can then be delivered into chutes and loaded on cars as desired. If it is to be broken by hand it should be done in place in the track. Draw enough broken stone to raise the track to proper surface, leaving the center empty; this is to be filled with large stone, to be broken in place by ballast hammers. This breaking also packs the stone firmly, and economy results from better work and easier loading and unloading of the unbroken stone.

Furnace Slag answers the purpose of ballast nearly as well as stone. It is extensively used in England where it is drawn from the furnace on an endless belt, and then suddenly cooled by application of cold water; this hardens and breaks it at the same time. The size to be broken to, and methods of handling are the same as with stone.

Burnt Clay is sometimes used in place of broken stone or furnace slag with reported good results. Very little recourse is had to it in this country, as stone or gravel is usually attainable.

Gravel. As a rule, gravel is the most easily and cheaply obtained good ballast; it should be of medium and uniform coarseness, and as free from loam and dirt as possible. It does not give as good drainage as broken stone, but still, if of good quality, water will percolate through it freely. It can be loaded direct from the bank by a steam shovel, and unloaded by a plough and cable, thus being handled without much expense. It is easily taken care of by trackmen, and can be tamped with a shovel if necessary. When properly filled in and neatly dressed off, it forms a most presentable track. The great objection to gravel is, that in dry seasons it is liable to become dusty. If there is much loam with it grass will grow, and in winter it is affected by the frost.

Cinders make a very cheap and serviceable ballast; they are porous, do not retain moisture, do not heave much with the action of frost, and can be easily handled with the shovel. In " mud " track, in the spring of the year, or at wet times when everything is very soft, cinders will often hold up a track where even good gravel would fail. They prevent grass from growing, and under light traffic will last several years. But their extreme dustiness should prevent their use on branch lines doing much of a passenger business, unless the expense of obtaining gravel cannot be incurred; but for side tracks and yards, or on lines which must be maintained at a minimum cost, cinders make a most excellent and economical ballast.

Mud is the cheapest type of material used for ballast, being merely the ordinary soil found along the right of way. In a continually dry summer it cakes under the action of the sun, making work very difficult upon the track; in fair weather a tolerable surface can be maintained, but is soon destroyed, however, by a few days of rain; in winter the frost causes it to heave very badly, throwing the track out of surface and line, and rendering it very difficult to maintain; in spring, when frost leaves it, it becomes very soft, allowing the ties to sink.

In this latter case, as good a remedy as can be applied, is to dig out the mud and replace it by a generous bed of cinders. The best method of treatment, however, of mud track is to get rid of it altogether. In any case and at all times efficient drainage is imperative.

TIES.

The question of ties is one that should command, on every road, the closest scrutiny. There is no economy in purchasing timber deficient either in quality or size. Ties are subjected to two deteriorating causes: decay, and the cutting into the wood by the rail. To which of these the tie will yield first, is dependent on local circumstances: viz., nature of ballast, drainage, kind of wood, and amount of traffic.

The action of the first cause is gradual decay, until finally the tie ceases to hold the spikes, or even to support the rail. The action of the second is to have the rail cut and work its way down into the tie under the pressure of the heavy loads upon it. This cut forms a receptacle for water, and rot sets in to aid destruction, until the tie has to be taken out as unfit for service, although sound everywhere else. In soft wood ties this latter is almost invariably (always on curves) the cause of failure, and frequently so with even the best hard wood ties when subject to the heavy traffic of modern rolling stock. The usually adopted length of ties is probably 8 ft., but as this means only about 18 inches outside of the center of rail bearings, it is better to make the length 8 1-2 ft. A variation of over 1 in. from the adopted length should not be permitted; first, because irregularity ruins the appearance of the track, and second,

because it gives the track an unequal bearing. In cross section, since the length of a spike is commonly 5 1-2 in., of which 5 inches goes into the wood, the tie should be 7 inches thick, or at least not less than 6 inches thick. Whatever the thickness is, it should be rigorously maintained without variation. When ties vary in thickness, they are buried to a different extent in the ballast, and therefore unequally affected by moisture, drainage and frost, with correspondingly serious tendency to injury to the track surface. Furthermore, in replacing old ties, if the new ones vary in thickness, the old bed must be lowered or raised to a different degree for each tie. Effect, rough track. Therefore the thickness specification should be strictly enforced. As to width it must be remembered that every wheel strikes a blow reaching to the ties beneath. Nearly all of the later types of engines have 11,000 to 16,000 lbs. on each driver. Therefore on a rail base of 4 1-2 inches and a tie 8 inches wide and an engine with 14,000 lbs. on each driver, a strain can be produced of nearly 400 lbs. on each square inch of wood surface. When it is considered that this strain is in the shape of a constantly recurring blow, and moreover, that the wood which has to resist it is subjected to exposure and decay, it can be readily seen that a face of 8 inches is none too large. From 8 to 10 inches will be found the most desirable widths, as presenting a good bearing for the rail, sufficient surface underneath to transmit the weight to the ballast, and as being a convenient size for handling. Ties under size are not only cut into more rapidly by the rail, but they are likewise driven down into the ballast. Large ties should be avoided as being of old coarse timber, more liable to decay, unwieldy to lift, and requiring too much "digging" to put into the track. As far as possible ties should be sorted as to size and quality, and laid with some degree of similarity; especially should the different varieties of woods be kept by themselves. Track laid in this manner will be found to wear more evenly.

Ties are either hewn or sawed, the latter on two or four sides. Hewn ties are preferable because they are more durable, since but one tie is obtained from each section, and thus the heart is protected. A hewn tie with the same face is a really larger tie than if sawed, on account of the rounding sides. A great objection to sawed ties is that they can be made from large, coarse-grained sticks, giving several ties to a section, and it is even possible to pass off old or dead timber when decayed portions have been removed by the saw. Cross-grained wood that cannot be hewn, can be sawed into ties, which are very liable to break, especially when frost heaves the track.

Ties sawed only on two sides, face and bottom, are equal to hewn ties, except that old tie-men claim that the adze in hewing closes the pores of the wood, while the saw leaves them open to absorb moisture and hasten decay. Ties sawed on four sides have one advantage—uniformity. Split ties should never be received, as the heart is exposed and they rot quickly.

Ties if hewn, should be made quite true, so as to give the rail an even bearing, and they should invariably be stripped of their bark, which will absorb moisture like a sponge, and, holding it against the wood, also cause decay. After a time the bark becomes loose; and when the trackmen attempt to tamp, it gets under the ties, interferes with the bars and prevents solid work, or else it will work up and show as an unsightly fringe along the edge. Finally, all ties should be cut from young living timber. That which grows on high ground is to be preferred to that growing on low; that which is cut in the winter when the sap is down, is considered the more durable. For inspection they should be piled up in square piles in alternate layers, every other layer having but two ties so as to permit free circulation of air. If the ties are to be stored for some time, the top layer should be inclined so as to shed the

rain. For convenience in loading they should be delivered on ground at least as high as "grade." The most common varieties of woods used are oak, chestnut, pine, cedar, hemlock, beech, maple, birch and cherry.

Oak.—This is the most desirable of all the woods, both for wear and natural durability, its value varying according to the species, though the exact classification in this direction is often difficult, especially when the bark has been removed. White oak is the best; it can be distinguished by the bark, and fineness of grain; it is very hard; resists abrasion by the rail, and is slow to rot. Its life even under heavy traffic is about eight years, although it sometimeslaststen or twelve years. It generally rots out. Rock oak is next in value to white; the bark is rough and not always easily distinguished from some other varieties of rough barked oaks. Yellow oak is a good wood but not the equal of the two preceding kinds; it will cut out, or rot out in from six to seven years. These are the only varieties fit to use. The others are known as black and red, names however that are frequently interchanged according to locality. They soon decay, their life being but four or five years, and sometimes less.

Chestnut.—This timber ranks next to oak. As regards resistance to decay it is superior to the latter, and for that reason always preferred for fence-posts. Under light traffic it may be used as readily as oak, especially on straight lines; its life may be as great as ten years according to service, but under heavy running the rail cuts into it and renders it useless in from five to six years. Chestnut ties have a serious tendency to split.

Pine.—Both white and yellow are extensively used, with durability in favor of the latter, which is very slow to decay. Its life under light service can be put down as twelve years, but under heavy work the rail has cut into it so far in eight years as to render it unfit for further use. Yellow pine is extensively used in the South.

Cedar.—As regards decay this is probably the most lasting wood we have, but it is too soft to withstand rail pressure, and in five years, or less time, has to be removed.

Hemlock.—A wood largely used on account of its abundance and low price, a practice far from economical. Lying buried in the ground soon causes rot to set in. It gets soft under the rails and around spike holes, and its life cannot be depended upon for over four years, unless the timber is of excellent quality and the traffic is light. Hemlock is a very treacherous wood, as decay starts inside, and a stick outwardly sound is frequently but a mere shell.

Beech.—Of this wood there are two varieties, red and white. The former is quite a durable tie under light traffic, lasting about five years, and is to be preferred over hemlock. The White Beech is quite worthless, becoming soft, and cutting out in three years.

Maple, Birch and Cherry.—Woods of not much practical value, as they soon go to pieces.

It should ever be borne in mind that there is no economy in buying inferior varieties of timber simply because they are low-priced. It takes no more labor to put in first-class oak, than poor hemlock, ties. The former will last more than twice as long, take less labor to maintain, give better service in the meantime and do not require the track to be so frequently opened to be re-tied, a proceeding which is always detrimental.

In Europe a large portion of the track is laid on longitudinal stringers instead of cross-ties, a method formerly considered the best, but latterly being superseded by the cross-tie system. These cross-ties are rarely of plain wood, but generally treated by some chemical preservative process, or else made of stone, iron or steel. This last material is receiving considerable attention, especially in Germany. The rails are fastened to the metal ties by various combinations of clamps, bolts or rivets. With high prices for wood abroad and diminishing cost of steel, it is probably the material of the near future.

Fig. 27 gives cross-section and plan of the metal tie of the Bergisch-Maerkische Railway of Germany, together with details of joint and fastening. After a long series of

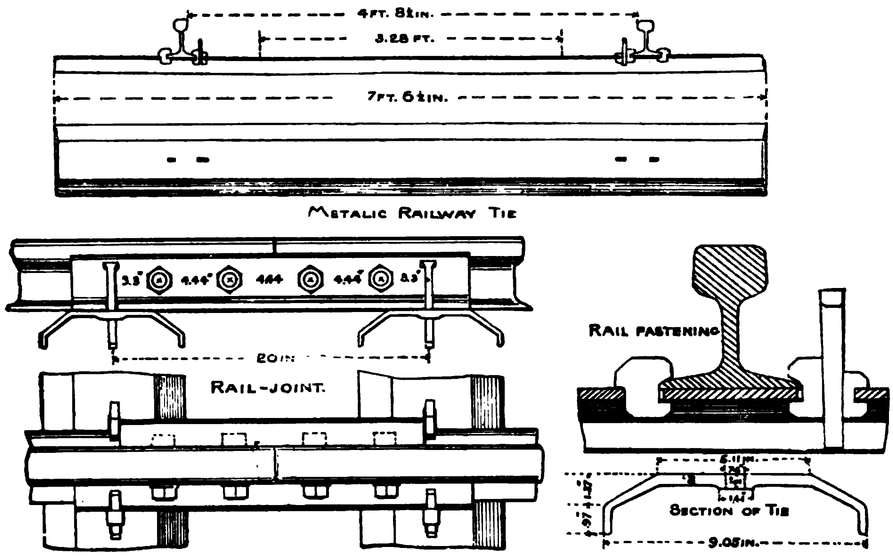


Fig. 27.—Metal Tie, Bergisch-Maerkische Railway.

experiments extending over many years, they finally arrived at the design as shown. The ends and sides of the ties are turned down to more completely hold the ballast, as at first this latter was found to have a tendency to work out. The ties are made of a mild steel, capable of standing tension tests of 64,000 lbs. per square inch with 15 per cent., of elongation, and weigh 99 lbs. each, with a length of 7 1-2 feet. In Germany they are worth $1.53 each, with metal at $34 per ton, while a creosoted wooden tie costs $1.40 to $1.50. The results of eight years experience with this form show that except in wet tunnels rusting does not take place; that there is a slight wear under the rail due to vibration caused by poor fastenings, a defect they claim to have remedied by the improved design as shown in the figure, and by making them of toughened iron; that breakage is slight, being only 172 out of 273,900; that the increased cost is more than compensated by the increased durability; that they are safer; and that the expense of laying and taking up are about the same as for wood. They recommend that the tie in design should be as simple as possible so that it can be entirely made by machine.

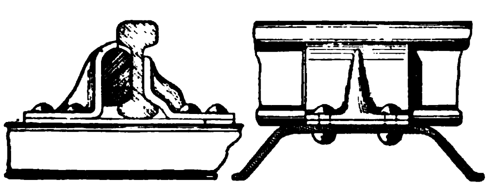


Fig. 28.—Metal Tie, London and North-western Railway.

As a sample of English practice there is shown in Fig. 28 a cross-section and details of Webb's steel rolled tie and chair as used on the London and Northwestern, the weight of the tie being 174 lbs. and length 9 ft.

Between the chair and tie is inserted a steel lining plate and sheets of brown paper soaked in tar to overcome any tendency to get loose and clatter. The chairs are of steel stamped out by a steam hammer. The key is wood which, it is said, does not get loose. A slight cant is given to the rail by the chair being set at an angle to fit the coning of the wheels, the same effect being obtained in the German tie by giving the whole a deflection. These ties of Mr. Webb, after use of over three years, give satisfaction, but require, as do all metal ties, that the drainage shall be perfect.

In this country, although the steel age may yet be in the future, still on account of the large and increasing amount of timber used annually in cross ties, with consequent rise in price, the prolongation of the life of the tie is already a question to be seriously considered, and some process will soon have to be adopted which will harden and preserve from decay our less valuable woods like hemlock, so that they can take the place of the scarce oak. The principal methods of preserving are the following:

Kyanizing.—The timber is saturated either by long immersion or great pressure, with a solution consisting of 1 lb. of chloride of mercury and 4 gals. of water. The cost is about $6 per thousand feet B. M., but the process is of doubtful utility if moisture be present.

Burnettizing.—A solution of 1 lb. of chloride of zinc to 4 gals. of water is forced into the wood. The cost is about $5 per thousand feet, or 25 cents a tie, and is probably the best process to use in this country for the preservation of tie timber.

Boucherie's Process.—The stick is impregnated by pressure, with a solution of 1 lb. of sulphate of copper to 100 lbs. of water.

Creosoting or Bethel's Process.—The timber is injected with hot creosote oil. This is the method which is most extensively used abroad, and is undoubtedly the best of all. But as 8 to 12 lbs. of oil are required for each cubic foot of wood, it costs in the United States about 50 cents per tie, and the expense forbids its use.

It is found that any process to be successful must be well done, and that as the life of prepared ties is materially diminished by the presence of moisture, the road-bed should be thoroughly drained. The general theory of all these processes is that the sap, the decaying agent, is expelled, and the wood cells filled instead with a mixture which prevents deterioration of the fibres, by keeping them free from the destructive causes.

Cross-Section.—In arranging the shape of the ballast and road-bed, and manner of putting up the track, great attention should be given to drainage. Unfortunately for good track, the importance of this subject is frequently under-rated. "Take care of the ditches and the track will take care of itself," might almost be made an axiom; at any rate it can be laid down as a law that no track can be good without drainage.

Ditches should be ample to carry off the greatest amount of water that can come into them even with a heavy rainfall, with the bottom sufficiently below the ties so that the moisture will run from them and keep the ballast hard and compact. The contour of the ballast should be such as to give a perfect support to the tie; keep it from movement either laterally, longitudinally or vertically; and to obtain this it is necessary to keep it dry; therefore it must be shaped so that it will not retain water. The upper diagram of Fig. 29 shows a cross-section of single track with "mud" ballast. The efficacy of mud depends entirely on drainage. Let water soak into it and it immedi-

ately becomes pasty—so that one day's rain may ruin weeks of patient surfacing. Therefore the ditches must be low, the lower the better, the bottom being at least 20 inches below the tie, and if the cut is 18 feet wide this will bring the lowest part, i. e. where the slope of the ballast meets the bank, 4 feet 9 inches from the end of the tie.

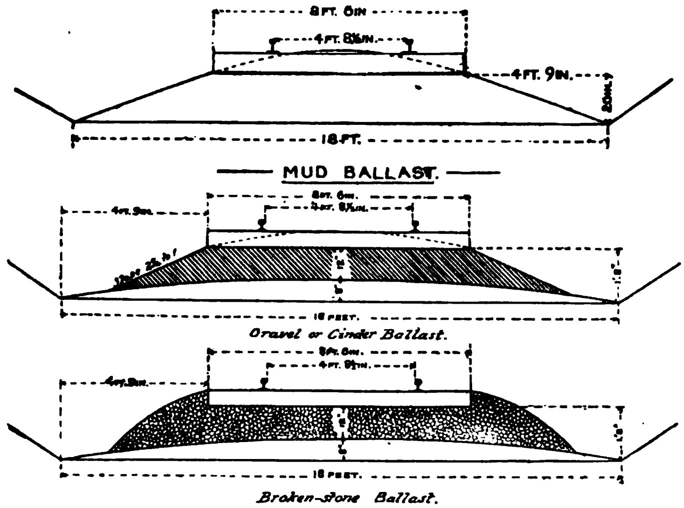


FIG. 29.—STANDARD SINGLE TRACK.

In the center of the track the mud should be heaped up about 2 inches above the top of the tie and then rounded off on both sides to the bottom of the end of the tie, leaving the whole end exposed. This crowning is done to run the water off quickly. Care should be taken to see that it is properly carried out, that the curve of the crown is such as to leave 1 1-2 inches under the rail, and that the end of the tie is not buried at all. If it is, then, under the action of trains in wet weather it will cause a trough which will retain water, and the consequent softening of the mud will allow the track to settle. If the tie is exposed at the end, the water that is on top runs off, while any that soaks underneath has an opportunity to run out. From the ends of the ties the mud must be sloped away until it reaches the bank as shown. No shoulder or anything that will retain water is required and therefore is to be avoided, and everything should be done with the aim of facilitating the passage of water into the ditches.

An example of this unnecessary shoulder is given in Fig. 30, showing standard of the Erie and Wyoming Valley R. R. While the arrangement of Fig. 29 is not guaranteed to give perfect track with mud, it is certainly the best scheme to take care of bad materials; for while drainage is essential to all track, no matter how good the ballast, it is the entire life of, and sole hope for "mud."

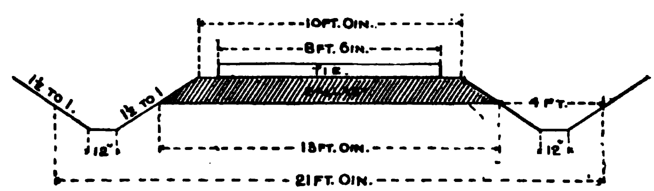


FIG. 30.—ERIE & WYOMING VALLEY R. R. CROSS-SECTION IN EARTH CUTTING.

With gravel or cinder ballast the conditions are somewhat modified. In construction the road-bed at sub-grade should be crowned 8 inches as shown in Fig. 29. Then the ballast at the thinnest point in the center should be 12 inches deep, thus making the bottom of the tie 1 foot 8 inches above the ditch. Between the ties the ballast should be filled even with the tops of them, it not being necessary with good ballast to raise it above the ties as with mud, but rounded off from the track center under the rail to the tie ends, leaving them bare as before, thence it should be carried with a regular slope of 2 1-4 to 1 until it meets the sub-grade. Water thus has a free and uninterrupted course from the center of the track into the ditch.

With stone ballast these conditions are still more varied. We are then dealing with a material through which water runs with perfect freedom, and which is not as compact as gravel, therefore the cross-section recommended for previous cases needs to be considerably changed. The sub-grade should be constructed as for gravel, upon which the stones should be placed 12 inches in depth in the thinnest part. Each stone should be so broken as to pass in any direction through a 1 1-2 inch ring and be as uniform as possible. Inasmuch as water will run through, and not off, the broken stone, it is not necessary to crown it when filling in between the ties. On the contrary it should be carried out flush with the top of them as far as the end, and then rounded off neatly as shown in Fig. 29.

The tie thus receives better protection from fire, and from damage by derailment, but more important still, the track is kept in better alignment. The tendency to work out of line is greater with stone than with gravel, unless the stone is finely broken, for though the sharp corners may eat into the wood, yet, if the ballast is coarse, the tie is held upon a few points on which it rocks to and fro.

As was said before, the matter of drainage should receive every attention, and it will be found economical to make all the ditches as permanent as possible. Where banks are liable to slide, they can often be held in place by sodding. At tunnels, or where water is liable to flow freely, it will be found in the end the cheapest plan to form the sides of the ditches of cement, thus rendering them permanent and ornamental at the same time. Where ditches have to be stopped by fillings for road crossings or such causes, they must be carried underneath. This is done preferably by using the ordinary sewer pipe, either cast-iron or earthenware, or else a common wooden box drain, their relative values being in the order named. The most permanent form of construction is always best and cheapest in the long run. The size of course depends on the amount of water to be carried, but as a minimum the diameter of the pipe should be 8 or 10 inches and the cross-section of the box 8 × 10 inches. (Fig. 31).

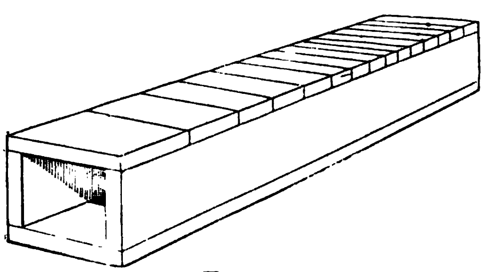


FIG. 31.
WOODEN BOX DRAIN.

If earthenware pipe is used, care must be taken to have it evenly tamped to prevent its breaking by unequal bearing. On long curves in cuts it is advisable to carry the water down on the inside of the curve so as to throw its cutting action against the bank rather than against the ballast. This is done by small drains set across the track at such intervals as may be necessary, at the mouth of which the outside ditch is dammed up so as to turn the water through the drain. They should be built of wood like Fig. 31; be put down at the bottom of the ballast, and be about 16 feet long.

With double track the arrangement of side ditches and outside slope of ballast is the same as with single track; hence that which has preceded is applicable to double track as well. There is, however, one new item to be considered, namely, the arrangement of the ballast in the space between the tracks. This space demands the same careful and systematic treatment as any other part, and therefore the ballast, if of gravel or cinders, should be sloped off as on the outside, thus forming a central ditch as shown in appended diagrams. The bottom of this ditch should be 6 inches below the ties. Each track, therefore, becomes as it were, a single track in which the ties are raised up by the ballast above the level on either side where water flows or may be

present. But the water which is thus collected in the central ditch must be carried to the outside ditches by a system of cross-drains. These drains are three-sided wooden

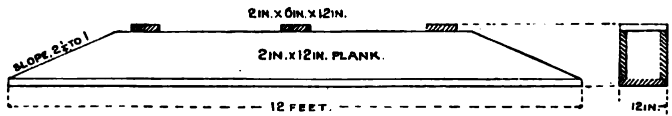


FIG. 32.

boxes about twelve feet long and made of 2 in. × 12 in. stuff stiffened with three

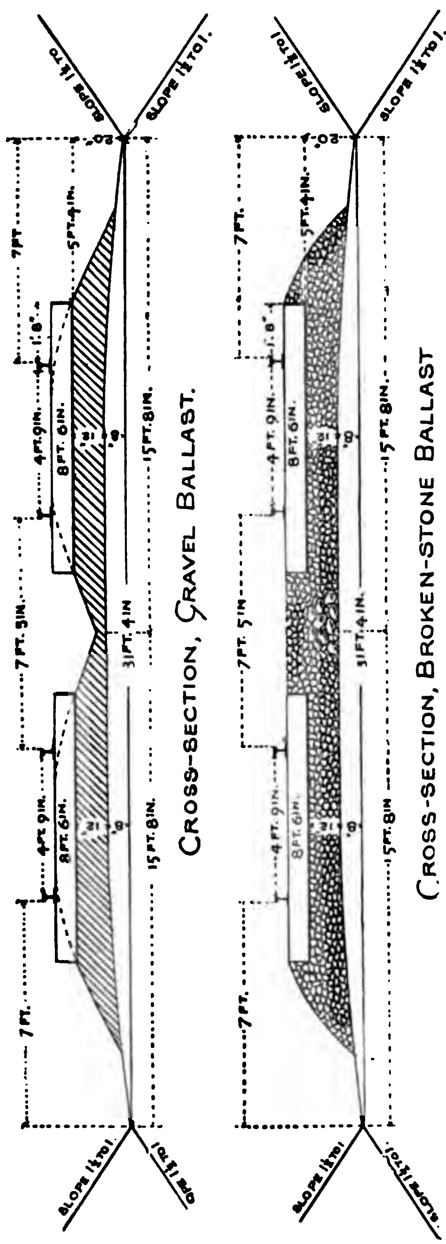


FIG. 33.—STANDARD SECTION OF ROAD-BED PENNA. R. R.

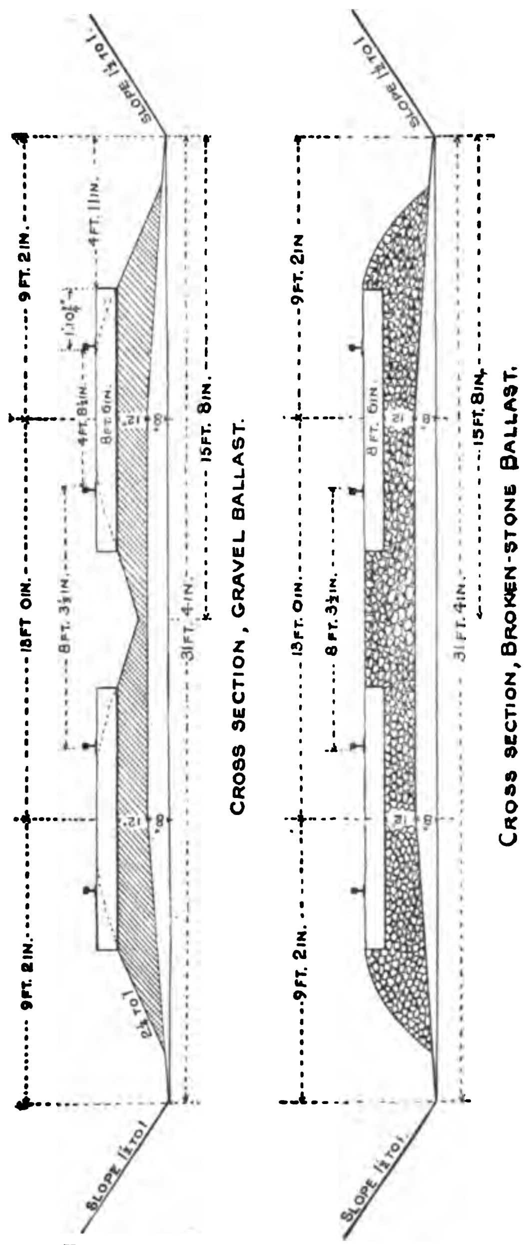


FIG. 34.—STANDARD DOUBLE TRACK CROSS-SECTION, N. Y., L. E. & W. R. R.

small braces and with the ends bevelled to conform to the slope of the ballast (Fig. 32). They are placed between the ties as often as occasion demands at places where water collects, as at foot of grades, etc.

When broken stone is the ballast, there is no need of a center ditch, because water runs through the stone and thence flows into side drains. Therefore, as was advised with single track to fill up flush with the ties, so in this case for the same reasons the ballast should be carried out level with the tops of the ties between the tracks.

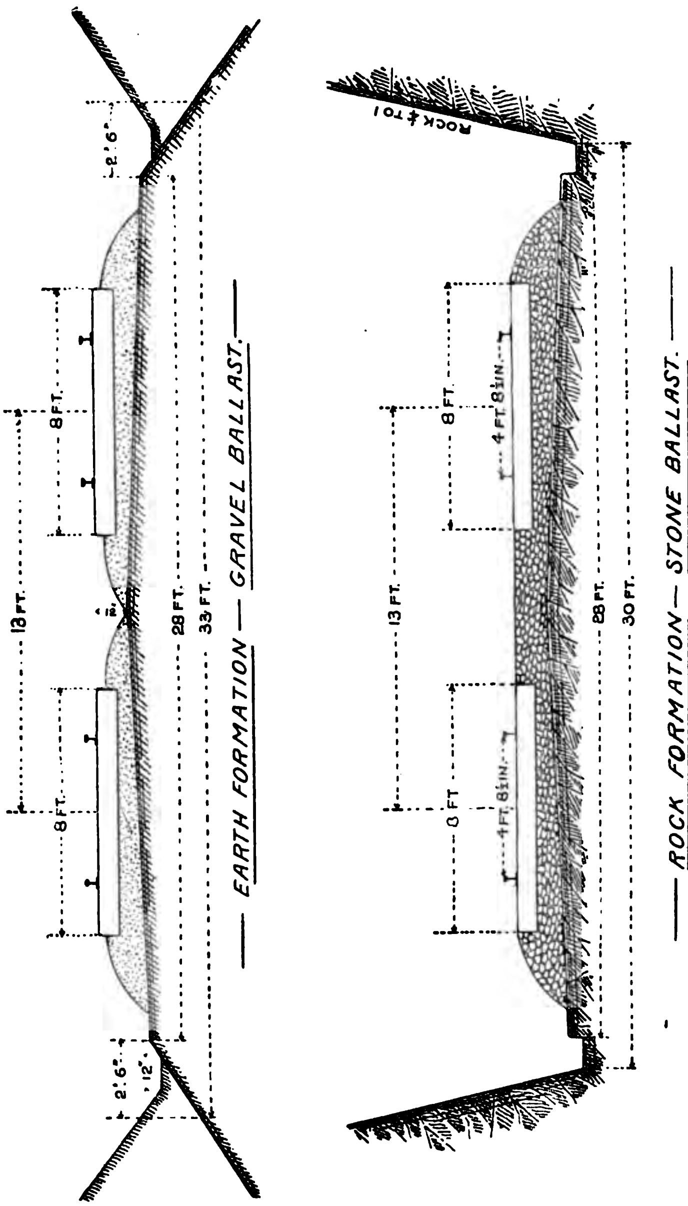


FIG. 35.—STANDARD DOUBLE TRACK SECTIONS N. Y., WEST SHORE & BUFFALO R. R.

Figs. 33 and 34 show respectively the standard cross-sections of road-bed for both gravel and stone ballast of the Pennsylvania Rail Road and the Bergen County Div. of the N. Y., L. E. & W. R. R. In important characteristics they are identical, the prin-

cipal variations being the distance between track centers and consequently the distance from rail to edge of ditch, since the total width of road-bed is the same in both cases. The greater distance between the Erie centers is due to the original broad gauge of 6 feet, but the distance of 13 feet is being generally adopted on new lines with double track, as it is an advantage to have ample space between tracks, to give passing trains full clearance and to afford better facilities for drainage.

In locating sidings, they should never be closer to main track than adopted standard. If the side track is on the inside of a sharp curve, the outside rail must be elevated to prevent the tops of cars striking.

Fig. 35 gives the standard of the N. Y., West Shore and B. R. R. whose principal points of difference from the other examples are the ditch formation and the gravel ballast carried half way up the tie ends. This latter might be permissible in perfectly screened gravel whose characteristics are similar to broken stone, but it is always best not to impede drainage.

On some roads it is the practice to shape the gravel ballast in the same manner as we have represented as the proper method for stone, claiming for it:

First—*Line:* Track keeps in better line as the ties are held laterally.

Second—*Frost:* Frost is prevented from getting under the ties.

Third—*Protection:* Ties and train are better protected in case of derailment.

The first two reasons are not sustained by fact, and while the third is partly valid, although really less so than it appears to be, it is more than counter-balanced by the many advantages of the "slope system," as the method advocated in this book can be called.

With this system the rainfall is at once collected on the whole road-bed and carried directly into the proper channels, while by filling in between the track and on outside, the water is prevented from running away, and has to be disposed of by the slow process of absorption; the ballast thus is kept wet for several days after a rain, letting the joints settle, preventing track work, and instead of keeping the track in line, really does not do so as well as when the tie ends are left bare, because when the ballast is wet the co-efficient of friction between it and the tie is much reduced and the track slides laterally that much easier.

The second reason might be to a certain extent true, provided the ballast were perfectly dry, but since winter is always preceded by, and accompanied with, wet weather, that track which is best drained and driest must suffer the least. With double track when the center is filled in, each track is differently affected on both sides by frost, on account of unequal filling; secondly, the mass of ballast lying between the tracks expands and throws both tracks out of line.

Opposed to such a method are all the previously enumerated advantages of the "slope system," together with a great saving in material, and especially in labor of maintenance, for the track can be more readily lined in either direction, at least 8 per cent. more ties can be put in with the same labor, and, on account of its drying more quickly after a rain it not only stays in surface better, but permits more working days.

In short, drainage is absolutely necessary, and on double line it is equally important to drain both sides of each track.

CHAPTER III.

RAILS—JOINTS—CHAIRS—SPLICES—BROKEN ANGLE BARS—BOLTS—NUT-LOCKS—SPIKES—BRACES

RAILS.

No part of a railroad has undergone such a complete change in material, form and fastenings as the rails. Without attempting to give the details, from a historical point of view, of the various processes of manufacture, as scarcely entering into the scope of the present book, we hastily sketch the steps of progression in form, at least.

The first tramways were of wood or stone; then was introduced the cast iron rail of L pattern, to be succeeded about 1805, by the cast iron "fish-belly" type in lengths of four or five feet supported on cast iron chairs, which was, in turn superseded, about 1820, by the well known "strap" rail, notable as the first attempt at rolling the iron into shape for this purpose. The strap rail was a flat bar of rolled iron, of various sections, spiked down to a longitudinal wooden stringer and is chiefly remembered for its unpleasant tendency towards the formation of "snake-heads," so called, the ends curling up and at times going through the floor of the car.

The first form worthy the name of rail from a modern standpoint, is the "double-head," shown in Fig. 36 A. A shape was thus obtained possessing sufficient vertical strength to permit its use as a girder between supports, having lateral stiffness, and supposed to be advantageously adapted to turning when one head had worn out. The double-headed rail, in various modified forms, is still very largely used on the continent of Europe, and especially in England, where it is supported on each tie by a heavy cast-iron chair.

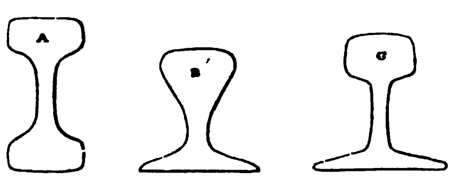


FIG. 36.--RAIL SECTIONS.

The next advance was the flat bottomed rail introduced by the English engineer Charles Vignolles, about 1831, and since known by his name. As this is the type now in exclusive use in the United States, we will confine ourselves solely to its consideration. The advantages over the double-headed rail are economy of material, simplicity of joint fastening, and the rejection of the cumbersome cast iron supports.

At first, the section adopted was that shown in Fig. 36 B, called the "pear" pattern. These rails were supported at the joints by cast or wrought iron chairs; but as this shape was not well adapted to heavy service on account of the difficulty of attaching proper fastenings, further experiments were made, and after trial with various sections, and investigation of rate of wear on both rail and wheel, the present style of rail, Fig. 36 C, was finally determined upon. In this latter form the material is located

with a view to its proper and economic disposition for service, and with minor modifications it has been almost universally adopted.

The divisions of a rail are the "head," "web" and "base," or, as they are generally termed by the trackmen, "ball," "neck" and "foot." In proportioning these parts, as much material as possible is concentrated in the head so as to withstand wear; the web is so arranged that with a given amount of metal the depth or vertical stiffness of the girder is a maximum, and the thickness a minimum, and the base should be as broad as possible so as to provide a good and sufficient bearing area and the greatest resistance against lateral deflection.

In the earlier stages of rail manufacture, bars of iron were placed in layers forming a "pile," and then heated and passed through a series of graduated rolls until the final rail section was obtained. The resulting rail was thus composed of many welded parts, more or less perfect in their union. As the traffic and the weight of the rolling stock increased, these wrought-iron rails began to give trouble by splitting, and more especially by the lamination of the head. To meet this then serious objection "steel" rails were introduced about 1857, and under the Bessemer process of 1862 the manufacture was rapidly developed and the cost of production reduced. These so-called steel rails are simply a high grade of homogeneous iron rolled from solid ingots and consequently without the objectionable weld. Until the introduction of the Bessemer process, the cost of production and the distrust of the new metal brought into the market an iron rail with a steel cap which was expected to meet all requirements; but actual use developed the impossibility of making a perfect union between the iron and the steel.

Improvements in the Bessemer process and the invention of the Siemens-Martin method of manufacture, soon decreased the cost and made it possible to furnish the steel rail which, at this date, has entirely supplanted iron. It is an undeniable fact that to this invention of Henry Bessemer, (improved by the late A. L. Holley,) the present marvellous growth of the railway system of the world, is in a great measure due.

As regards weight and size of all rail required, the minimum weight economical in practice is 60 lbs. per yard with a base of 4 inches. This is sufficient for roads doing a light or exclusively freight business; many roads, especially in the southern States, are being run with lighter rails than this, but the diminished life of the ties and the increased cost of maintenance more than counterbalance the extra cost of heavier rails. A 63 to 65 lb. rail will answer for heavy freight and good passenger traffic, while for extra heavy service with very fast passenger trains a 67 or a 72 lb. rail is needed. The heavy rails do not bend so easily, the joints do not sag so quickly, and the track stays in much better line. Of course a heavy rail requires more men in a gang to handle it and to throw the track, but when once in place it is more permanent. Another and considerable advantage is the broader base and consequent increased bearing upon the ties, for as mentioned previously these ties succumb as often by being cut out as by being rotted out; therefore the rail base should be broad and rounded at the sides as shown in the Penna. R. R. pattern, and not brought to a sharp edge as in the majority of rail types.

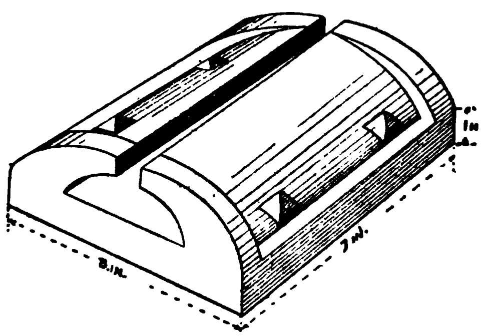
JOINTS.

The weakest part in the track is the joint, the one detail which above all the rest needs most attention and time in order to insure a smooth and easy riding track. For a joint to be perfect it should be: First, as strong and elastic as the rail itself, and second, the parts should be simple, readily replaced and permanently secure.

There is no joint which entirely fulfills the above requirements, and to appreciate

the difficulty of the problem one need but watch the pounding of a passing train on what at present appears to be the necessary gap at every joint. Suddenly, from its state of rest, the joint is disturbed by a blow from a driver carrying 7 tons and traveling at the rate of 40 miles an hour. Then will come a series of rapidly delivered blows of 3-4 to 1 1-4 tons each at irregular intervals as the body of the train passes over, and again suddenly the weight is taken off and the joint allowed to settle back to rest through a series of hurtful vibrations. After this a slow, heavily loaded freight train perhaps will follow, where the effect of the ponderous "consolidation" will be one of slow pressure rather than the decisive blow of the express "flyer," and behind it come, with varying intensity of weight and force, 250 or more wheels of the following train. This incessant hammering, at all times greatly varying both in weight, intensity of force, and rapidity of repetition, the joint is expected to stand.

Under the requirements of a perfect joint the quality of strength is easily understood, and by elasticity is meant that inherent power of bodies to return to their original shape. Thus as a wheel rolls over a rail, the rail is depressed, and by its own elasticity and that of the ballast, it returns to its former position after the wheel has passed by. To say therefore, that the joint must be equally elastic with the rail, means that it will depress under passing loads to the same extent, and also spring back with equal elasticity to its former position. It is keeping the joints in order that consumes such a large percentage of track labor. The incessant pounding they are subjected to, their lack of strength and elasticity and the tendency of the parts to loosen, soon make the joints begin to sag. Therefore the importance of keeping the roadbed in good order can all the more be appreciated, and the ballast especially should be perfectly drained so as to insure to the joints as firm a foundation and constant condition as possible in order to best withstand the necessarily varying blows.



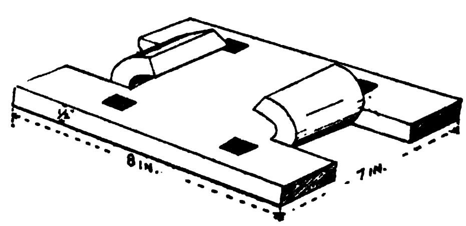


FIG. 38.—WROUGHT-IRON CHAIR.

FIG. 37.—CAST-IRON CHAIR.

Joints are of two kinds: *supported* when a tie is immediately under the joint and *suspended* when the joint falls between two ties. The theory of the first is, that resting on a tie a direct substantial bearing is obtained to resist the blow of the wheel as it strikes the expansion space. In practice, however, since the joint must be solidly tamped, this blow is transmitted to a hard, inelastic foundation, especially when the ground is frozen. The effect is of a shattering nature, and a series of repeated blows loosens the tamping and gradually lowers the joint. The suspended joint is superior to the supported, and gives better results, on account of the sustaining power being derived from two ties instead of one, and on account of the elasticity of the rail ends

and splice-bars which act as a cushion to ease the blow of the wheel. The fastenings, however, must be of sufficient strength to act as a girder, otherwise the rails will bend.

The earlier shapes of "T" rails, like the Pear section, had the joints necessarily held in chairs of either cast or wrought-iron as shown in figures 37 and 38, but which are now practically obsolete. The great objection to these chair joints was first, that they were necessarily supported, which, in addition to the already mentioned disadvantages, is frequently annoying when laying new rails over old ties, as it necessitates the moving of the ties to catch the joints unless the new rails are of the same length as the old. Secondly, a perfect fit between rail base and chair is impossible, consequently there is an incessant clatter. Thirdly, unless all bearings are true and joined in surface, either the chair of cast-iron is liable to crack, or else the corners of the rail base will break off and permit side motion in the rail ends. Creeping of the rails with these joints is prevented by spiking both chairs and rails together to the ties, by means of holes made in the chairs (see figs.) and slots punched in the base of rails to correspond.

FIG. 39.—THE FISHER JOINT.

The chair joint has been considerably elaborated, finally resulting in several types of suspended joints, to which the term chair is hardly applicable. Decidedly the best of these is the "Fisher," Fig. 39.

Its advantages are that it is a suspended joint and has its material distributed economically, since it is all at the bottom of the rail, thus virtually adding to its depth; it moreover gives support to the whole end of the rail which cannot deflect until the chair does. The Fisher joint is held by a much larger bolt than can be safely put through the web of a rail and therefore permits the nut to be screwed down with greater force. This vertical bolt also prevents creeping, since the rails butt against it, the corners being drilled off to receive it. This joint, still somewhat in an experimental stage, although giving most excellent results, has one disadvantage common to all joints whose members lie between the rail and tie; the joint ties must be cut down, with a tendency to split and extra liability to rot, or else they must be lowered. If they are lowered it is done by inclining them (unless the joints are "opposite"), when the surface of the ties and that of the rail base are no longer in parallel planes, thus giving the joint uneven bearing.

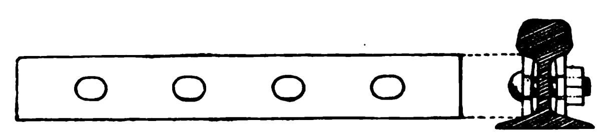


FIG. 40.—FISH-PLATE.

The first step in advance over the old-fashioned chairs was the "fish-plate" which began to come into general use about 1847. Two straps of iron were bolted to the rails, as shown in Fig. 40, and it received its name from the sailor's term of "fishing" a joint on the same principle. They vary in length from 15 to 24 inches; in height according to rail section, and in weight from

8 to 14 lbs. a piece. They are held by 2, 4, or 6 bolts, generally 4. The spacing of these bolts follows no rule, but varies arbitrarily with each road. Such a joint can either be suspended or supported, but unless the plates are very heavy and traffic light, it is best to use them supported. The metal is not well distributed to give much vertical strength, and if they have to carry weight, as in a suspended joint, they will break. To prevent this breaking, a plate reinforced in the center, and called the Samson bar, has been invented. To prevent creeping with the fish-plate

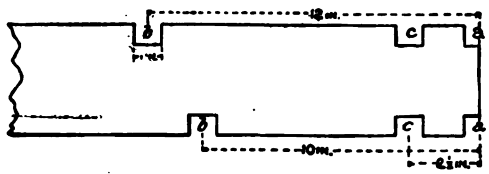


FIG. 41.—SLOT IN BASE OF RAILS.

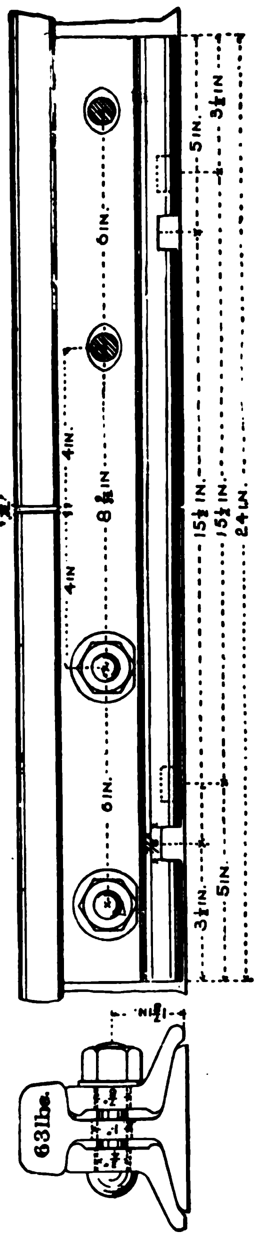


FIG. 42.—STANDARD JOINT, N. Y., L. E. & W. R. R.

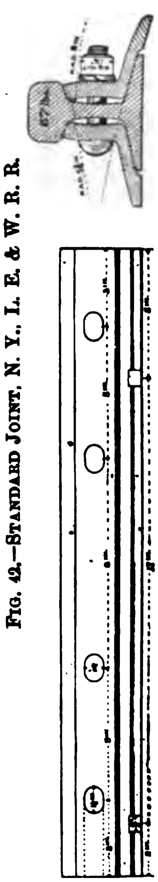


FIG. 43.—STANDARD JOINT, PENNA. R. R.

joint, the corner of the base is cut away sufficiently to hold a spike, or else back from the end a proper distance if a suspended joint is required. Sometimes, however, instead of cutting away the corners, slots are punched about 2 inches back from the end so that there is room for the slots of both rails on the same tie. This gives 4 spikes instead of 2 to the joint. Fig 41 shows the three styles marked respectively a, b, c If a rail is spiked in warm weather, the spike must be driven on that side of the slot away from the end of the rail, thus allowing the rail to contract and expand, though in narrow limits. In order to give a plate joint sufficient strength to act as a suspended joint, an angle bar weighing from 15 to 20 lbs. a piece, instead of a straight bar, is used as shown in Figs. 42 and 43, the standard joints of the N. Y., L. E. & W. R. R. and the P. R. R., respectively. Such a joint, varying only in details of size of plate and spacing of bolts, is the generally adopted standard of the day and hence claims our attention at length.

The first advantage over the straight splice is obtained by having the increase of metal at the bottom adding to its vertical strength and thus justifying its use as a suspended joint. Again, the strength of the joint is materially increased laterally, since rails have not only to resist vertical but lateral strains, and on a curve, unless they are carefully bent previously, they tend to straighten and ob-

tain the amount of curvature by deflecting at the joints. This tendency is counteracted by the lateral stiffness of the angle bar.

Furthermore, as the bottom of the angle is turned over the base of the rail it gives an increased bearing on the ties, and what is a still greater advantage, permits the plates to be spiked independently of the rail. In both the chair and fish-plate joints the rails are held from creeping by spikes driven in slots in the rails themselves, which is a great mistake. When the rail has expanded or contracted until it is fast against the spike, any further movement must be obtained by crowding the spikes.

If a rail is to be spiked in a slot it should be at the center. All this is obviated in the angle plate, the slot being cut in the flange of the angle. Now, while each rail is free to contract and expand to the limit, the string of rails as a whole is firmly held against creeping or running. These spikes, moreover, hold the plates in place even after the bolts loosen. Hence we can sum up its advantages as follows: First, increased vertical and lateral strength with elasticity retained. Second, suspended joint. Third, track is held from creeping, although each individual rail is allowed to expand freely. Fourth, perfect simplicity.

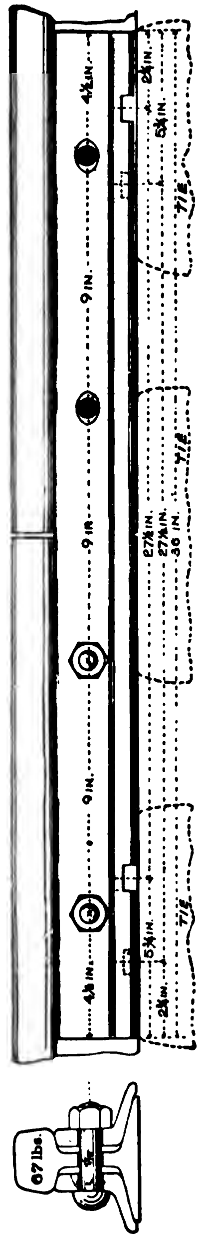


FIG. 44.—STANDARD RAIL JOINT, N. Y., W. S. & B. R. R.

The sizes of the plates should be so proportioned as to afford as nearly as possible the same strength as the body of the rail, (many of the present angle plate joints give but about 60 per cent. of this) and yet retain the same elasticity so as to transmit unbroken the wave of depression. A sort of combined supported and suspended joint is that shown in Fig. 44, the standard of the N. Y., West Shore and Buffalo R. R.

Its adherents claim that the arguments against a supported joint are not applicable to this, for although there is a tie under the joint, it is merely an aid to the weakest point and not the main support, which is given by the long plates resting on the two adjoining ties. There is thus obtained the advantage of the support of the one, and elasticity of the other form of joint, and a bearing on three ties. The adverse criticisms are, as in a bridge, that it is impossible for two separate systems to act together; in the end one of them will do all the work. So here, even if the three ties could be so tamped as to allow each to carry its due share of the load, it is not possible for them to remain so; either the center tie will be packed too hard, making a weak and cumbersome supported joint, or else this center tie will be slack, and the joint be a long and very weak suspended one.

More probably, however, the third tie (calling third in direction of traffic), the one which has to resist the "drop," will be the one to loosen, leaving the other two firm; then the plates will break at the joint. Another objection is the necessarily small space between the joint ties, which is but 6 inches, if they are all 8 inches face, not leaving room enough to tamp. The joint of the Michigan

Central R. R. is much better than the West Shore design, where the splices, are held by 6 bolts, are 44 inches long, so that there are about 9 inches between ties.

As was previously remarked, one of the great causes of weakness in the joints is the, at present, apparently necessary expansion space between the rail ends. Every wheel that strikes it is made to jump and "drop" on the rail head about 4 inches from the joint, and it is here that rails first begin to give out. Many attempts have been made to remedy this drop. Some years ago the N. Y. Central tried unsuccessfully a rail in three sections, split longitudinally and laid so as to break joints. Several kinds of joint fastenings have been devised to carry the wheel tread over the gap, but they wear unevenly and soon fail. In 1867, Chief Engineer Robert H. Sayre, of the Lehigh Valley R. R., began experiments with a skew joint shown in Fig 45, at which time he laid twenty iron rails cut at an angle of 60°. They wore out without the joints showing any defect. About two years ago the Philadelphia and Reading, and the Lehigh Valley each laid a string of skew joints, some cut at an angle of 60° and some at 45°, all of which are doing well. The experiments thus far conducted seem to show that the skew adds materially to the strength of the joint, and certainly to the easiness of the riding of the track. The inconvenience of patching a break with such a joint can be overcome by having on each section a half rail with one end cut skew and the other square.

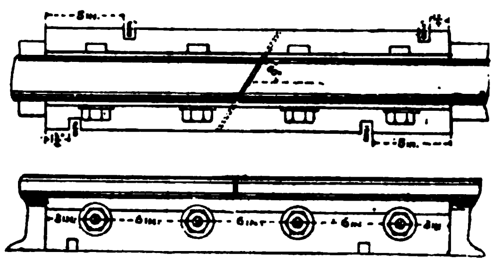


FIG. 45.—THE SAYRE JOINT.

The continual hammering caused by the "drop" either breaks the angle plates or gives them a permanent sag. To correct this (and it should be done), some roads replace all their plates every two or three years. The life of the plates, however, and with them that of the joint, can be materially lengthened by keeping the joint ties always sound and well tamped. The ties on the "drop" side of the joint receive the force of the blow, and are always the first to loosen, therefore they should especially engage the trackmen's attention. The failure to keep them firm is the general cause of broken angle plates.

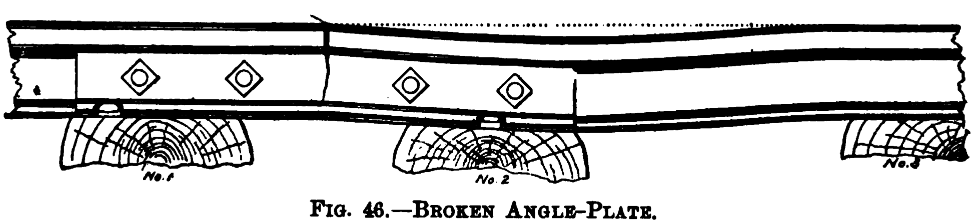


FIG. 46.—BROKEN ANGLE-PLATE.

So when the angle plates break, it must not be attributed entirely to their weakness, unless they give by sagging in the center; examine the track and see if the prime cause is not there, with a condition of affairs of which an exaggerated view is shown in Fig. 46. It will be found that the tie just past the joint is either rotten or loose, so that when the weight is on the rail, the latter deflects and bends down the plate, bringing a strain of tension at the top. If this strain exceeds the strength of the plate the latter will break in the center. A splice bar is intended to act as a girder, and the strain in the bottom of a girder supported at both ends is tension; therefore when the

plates tear apart at the top it shows that the strains have been reversed, and Fig. 46 explains this occurrence. It is a sure sign of defect in the track, and it will pay to watch it closely.

When angle plates are found broken they should be at once replaced, and the breaking cause, if in the track, should be removed.

The next question is whether in laying track the joints should be placed "opposite" or "broken." With the old fashioned chairs, joints were always opposite. Ballast was poor and joints were weak, and it was preferable to ride with a series of vertical jumps, rather than oscillations. Even the early forms of splice bars were but little more than hinges, and scarcely remedied the defect.

With the present improved angle plates, which approximate to the strength of the rail, the decided tendency of good practice is toward broken joints, although some claim even now, that in poor ballast it is best to have them opposite. But the author, after an experience in all kinds of good and bad ballast, is decidedly in favor of broken joints under all conditions, on account of less labor of maintenance and better riding qualities. Those who will examine a piece of track laid with broken joints will notice on the rail opposite each joint a spot of increased wear, seen most clearly when light is reflected from it. This shows that the jump caused by a joint is transmitted by the track to the other rail and produces a deteriorating effect thereon. Now suppose the joints opposite, the pounding on each rail caused by the joint would be increased by a sympathetic jar from opposite mate. Joints get low much more quickly this way, and the labor to keep them up, is decidedly increased.

The oscillation objected to in broken joints is more fancied than real, for when the joints are broken, one side of the track is always traveling on an even bearing, while both sides strike the joints together when they are opposite.

In question of line the value of broken joints is still more apparent. Unfortunately the strength of joints is still inferior to that of the rail, and when laid opposite, the weak parts of both strings come together; hence on curves the track tends to form angles at the joints, and the increase of labor in keeping track with opposite joints in line on sharp curves varies from 10 per cent. to 25 per cent.

BOLTS AND NUT-LOCKS.

The bolts used are generally 3-4 inches in diameter and 3 1-2 or 3 3-4 inches in length, according to the thickness of the rail and plate combined and whether or not a nut-lock is to be added. The bolt holes in the rail are drilled one inch in diameter in order to allow expansion room: while to prevent the bolt from turning, when the nut is tightened, the hole in the plate is punched oval to fit the enlargement of the bolt shown in Fig. 47. The nuts are made either square or hexagonal; the choice, unless governed by form necessary to fit the splice, is a matter of preference.

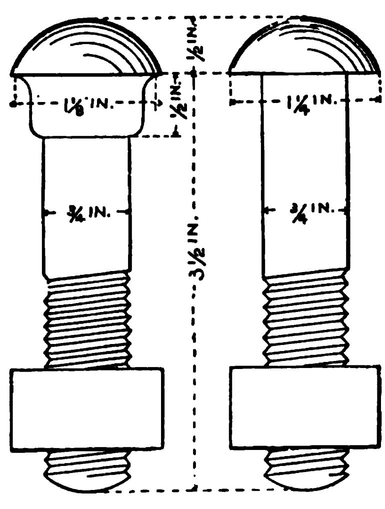


FIG. 47.—RAILROAD BOLT.

We now come to the all important topic of loose bolts and their remedy. Any nut under constant vibration will work loose. If the thread is very carefully and

accurately cut, as in fine machine bolts, this tendency is very considerably reduced, but with track bolts, where cheapness is insisted upon, and consequently the cutting of the thread slighted, the fit between bolt and nut becomes imperfect, and the rapidity with which a nut will back off seriously increased. Now it is *absolutely necessary* for good track, that the bolts should be kept tight; if not, the plates are not held firmly in place, their strength is materially and rapidly diminished, and the joint not only becomes low, but worse still, if allowed to stay so, the ends of the rails are permanently bent. Therefore tight bolts must be insisted upon. The question of remedy is one that long since has received the attention of inventors, the number of patents taken out being many of more or less utility, principally the latter.

The requirements for a good nut-lock are as follows: First, absolute simplicity. Second, durability and permanence. To comply with the first, the parts must be few, readily adjusted and taken apart, and without any complexity whatever. When it is considered that a foreman on a double track section of four miles has nearly 12,000 bolts to look after, the force of these remarks is appreciated. Any form of nut-lock which requires special tools, or is in several parts, and needs adjusting or care in putting in place, on account of the very large number of bolts to be attended to, will probably cause many of them to be neglected, especially in the hands of non-mechanical labor. The second requirement means that the locks shall be strong, capable of receiving rough handling and of being subjected to heavy strains, and especially be permanent and not affected by the weather.

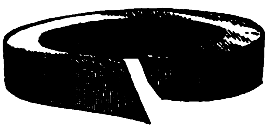


FIG. 48.—VERONA NUT-LOCK.

The different forms can be divided into three classes, according to the principles upon which they depend.

First, springs; second, elastic substances; third, miscellaneous.

The best representative of the first is the Verona nut-lock, Fig. 48, which is in more general use than any other lock, and depends for its efficiency on the elasticity of the iron itself to provide a spring between the nut and the splice bar. It is an excellent lock, but not infallible. There are a large number ot devices constructed on this principle, being mostly, however, more complicated and inferior to the simple Verona. Some of the variations, made in steel, have sharp points, or studs, which are expected to be driven into the softer iron of the bar and nut.

The second class depends on a solid cushion between the nut and plate. Of these the simplest, and of course unpatented, is a block of hard wood which is put on the outside of the joint as shown in Fig. 49, and the nuts are screwed down tight against an iron washer between it and the wood, thus giving an elastic cushion to take up the vibrations. Its size is entirely arbitrary, from 1 to 2 inches in thickness, and long enough to carry all four bolts, or else it may be in two smaller pieces, one for each pair. Although this works satisfactorily when new, it is objectionable on several accounts. First, the wood softens and decays, and the bolts must soon be retightened, an operation which has to be repeated from time to time for about two

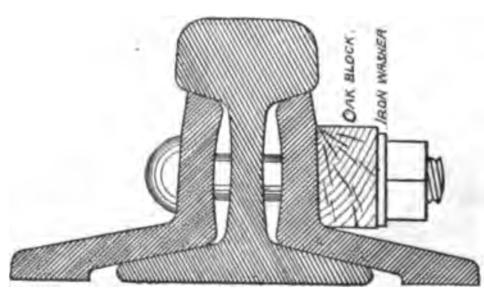


FIG. 49.—WOOD NUT-LOCK.

years, when the value of the block is gone. Second, in cases of derailment all the bolts will be broken. Third, it is unsightly.

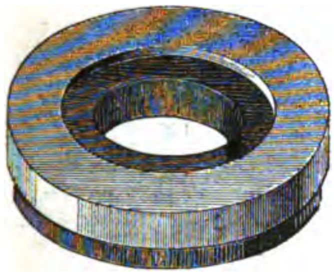


FIG. 50.—VULCANIZED FIBRE NUT-LOCK.

The vulcanized fibre washer, Fig. 50, is another widely used and effective lock, but like the wood proves a victim to decay, and hardens by exposure, while it is sometimes crushed under pressure. To obviate this latter, and give better protection against the weather, the iron clad form has been invented with a metal cap as shown in the diagram.

The third or miscellaneous group embraces a multitude of forms, among which are many good styles of jam nuts, but which are too complicated for track use, as can be said of the large number of devices with wires wedges, and locking plates. The most notable example of group No. 3, however, is the "Harvey," which best answers the requirements of a perfect lock. The principle is shown in Fig. 51; a slightly varying thread in the nut which, by the act of setting up, is squeezed into an absolutely tight fit by the thread of the bolt. In point of life it will last as long as the bolt, and is quite as durable as any of the other forms. Its great merits lie in its efficacy and entire simplicity, since the whole is contained in the nut and bolt without any additional parts. It is impossible for a trackman to lose or misplace it. When the bolt is in and the nut set up the lock is there too.

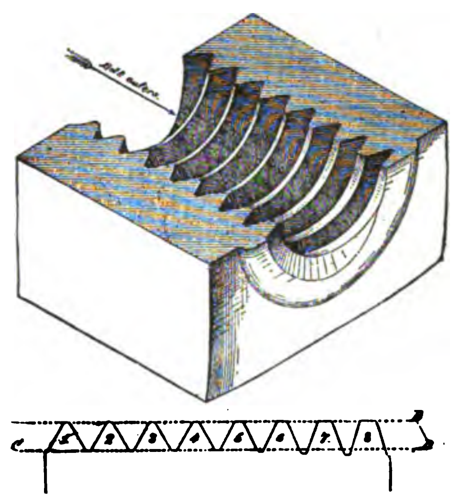


FIG. 51.—HARVEY NUT-LOCK.

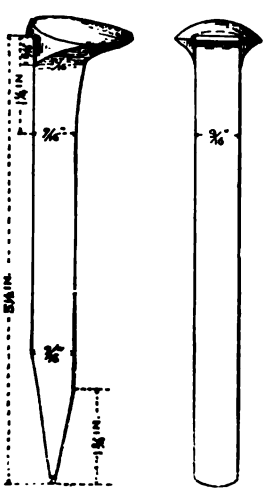


FIG. 52.—RAILROAD SPIKE.

The usual dimensions of a track spike, Fig. 52, is 5 1-2 inches long and 9-16 square, and it weighs about 1-2 lb., generally put up in kegs of 200 lbs. each. They should be straight, snug up to the rail and be kept there. Every tie should be spiked, and to prevent slewing, the inside spikes should both be on one side of the tie, and the outside spikes on the other, as in Fig. 53. So that, whichever way the tie tries to turn it has one pair of spikes resisting. This is a simple, practical detail often neglected.

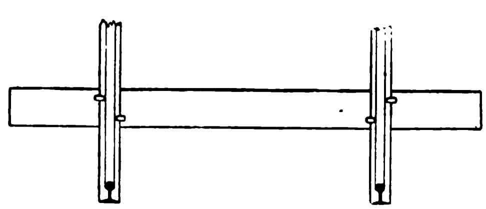


FIG. 53.—ARRANGEMENT OF SPIKES.

To hold rails on very sharp curves where the ordinary spikes have not sufficient strength, the Bush Interlocking Bolts, Fig. 54, have been invented. Two bolts are driven into holes bored by means of a special guide tool and then turned to grip each other in notches; the nuts are

Fig. 54.—Bush Interlocking Bolts.

then screwed down fast. Their expense prevents their general use, except in special cases.

For very sharp curves, guard rails, and in fact all rails which have to resist a strong side thrust, cast-iron "Knee-Braces" are used.

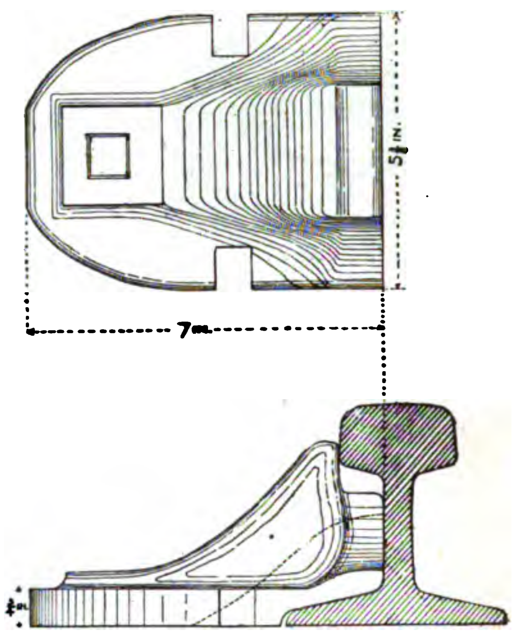


Fig. 55.—Knee-brace.

Fig. 55 shows a very good form, the weight of which is about 9 lbs. Its center is cored out according to the dotted line in order to save weight and so that it can be set over the regular spike. The top of the brace gives support to the side of the rail head as well as the web, a feature not generally seen in other designs, while to allow vertical motion of the rail independently of the brace, which occurs when the rail sinks into the tie under a load, the under part does not come up to the under side of the head by half an inch. These braces should be used on all curves over 8°, on lead rails of turnouts where running is fast, against guard rails, bolted and keyed frogs, etc. For 8° curves, two braces to a rail are the minimum, and more to be used according to increase of curvature, traffic and softness of the ties.

The material required for one mile of single track railroad—which when laid with 30 feet rails has 176 joints—is given as follows:

94 $\frac{640}{2240}$ tons (60 lbs.) rail.
2816 cross ties (16 to a 30 feet rail).
704 splice bars.
1408 bolts (9 kegs, 150 lbs. each).
11264 spikes (30 kegs, 200 lbs. each).

CHAPTER IV.

TURNOUTS—CONNECTING RODS—HEAD BLOCKS—HEAD CHAIRS—SWITCH-STANDS—SWITCH LAMPS—FROG DIAGRAM—TURNOUT DIAGRAMS—CAST FROGS—RAIL FROGS—CROSSING FROGS—SAFETY SWITCHES—POINT SWITCHES—SAFETY SWITCH-STANDS—WHARTON SWITCH—SLIPS—PUTTING IN TURNOUTS.

TURNOUTS.

The arrangement for passing from one track to another is known as a Turnout, the essential parts of which, with their respective names are given in the accompanying diagram, Fig. 56. The device for allowing the flanges of the wheel on one track to cross the intersecting rail of the other is termed a Frog, so named from its resemblance to the "frog" in a horse's hoof. The simplest method of passing from the main track to the turnout and the one in most general use, is to have a connected pair of rails so arranged that while one end is a fixture in the main track, the other can be moved so as to be a part of either the main track or the turnout. This is called the "stub" switch. That end of these rails which is fixed is called the "heel" and originally they were hinged here by means of chairs or fish

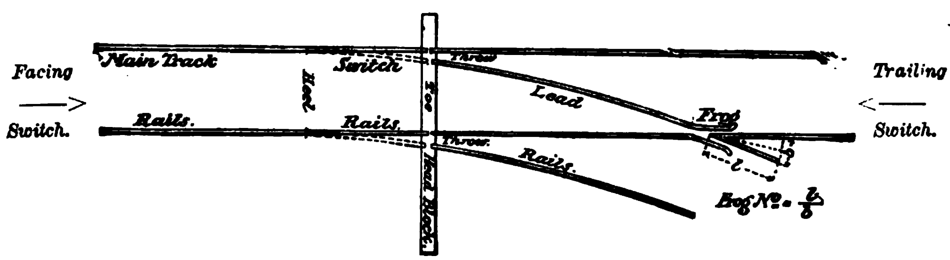


FIG. 56.—FROG DIAGRAM—GIVING NOMENCLATURE OF PARTS.

plates, so that when the loose end called the "toe" was turned for the turnout, the rails were straight and formed an angle at the heel. These rails are variously known as "switch," "swing," or "moving rails" and are held together by "switch-rods." The toe rests on a large piece of timber, called the "head-block," on which are placed the "head chairs" and "switch-stand." The rails between the head-block and the frog, which belong entirely to the turnout, are called "lead-rails." When the switch turns out on the right side it is called a "right hand" turnout, and when on the other side it is a "left hand" turnout; right and left having reference to a person facing the switch, and Fig. 56, which illustrates a right hand switch, shows also a single turnout or a "single-throw" switch; but when there is a right and left combined, that is, a switch in both directions at the same point, it is called a double turnout or a "three-throw" switch. A "crossover" consists of a single turnout, in each of two parallel tracks, with a connecting piece of track between them, so that trains can pass from one of the parallels to the other. In this case it is evident that the turnouts are both "left" or

both "right," as the case may be. A "facing" switch is one where a train running on the main track passes from the head block to the frog, while a "trailing" switch points in the opposite direction. This is explained by the arrows in Fig. 56.

Such is an outline of the various parts which we will now consider in detail. The line or curve given to the lead-rails should be circular, and scientifically considered as joining two tangents, one of which is the side of the frog, and the other the opposite main track rail. Let it be carefully understood that the term main track is used here merely to distinguish that track from the turnout. Now, since the line of the lead-rail is a regular curve joining two tangents, the switch-rails when thrown should conform to it. Instead of hinging them at the heel, they should be spiked for a certain part of their length (depending on frog number, gauge and throw); then when the toe is thrown the free portion will bend to an arc of a circle and fit the line of the lead. By knowing the frog number, gauge and throw, it is an easy matter to calculate the distance from frog to head block, and the length of the moving rail necessary to carry out the same curve can be easily calculated.

Such results obtained from various frog numbers, throw of 5 inches, and standard gauge (4 feet 8 1-2 inches) are given in Table No. 1.

TABLE No. 1.—Dimensions of Single and Double Turnouts.

Frog Number	Frog Angle	Head Block to Frog Point	Length of Moving Rail	Total Lead Heel to Frog Point	Tangent	Radius of Turnout Curve	Degree of Curvature	Head Block to Crotch Frog	Angle of Crotch Frog	Number of Crotch Frog
		FT. IN.	FT. IN.	FT. IN.	FT.	FT.		FT. IN.		
5	11° 25′ 16″	33 1	14 0	47 1	23.78	235.42	24° 31′	19 4 1-2	16° 08′ 19″	3.527
5 1-2	10° 23′ 20″	36 4 1-2	15 5	51 9 1-2	26.11	285.85	20° 13′	21 3 1-2	14° 40′ 56″	3.881
6	9° 31′ 38″	39 8 1-4	16 9 3-4	56 6	28.45	339.00	16° 58′	23 2 1-2	13° 27′ 57″	4.235
6 1-2	8° 47′ 51″	43 0	18 2 1-2	61 2 1-2	30.79	397.85	14° 26′	25 1 1-2	12° 26′ 07″	4.589
7	8° 10′ 16″	46 3 3-4	19 7 1-4	65 11	33.13	461.42	12° 27′	27 0 3 4	11° 33′ 04″	4.943
7 1-2	7° 37′ 41″	49 7 1-2	21 0	70 7 1-2	35.47	529.69	10° 50′	28 11 3-4	10° 47′ 02″	5.297
8	7° 09′ 10″	52 11	22 5	75 4	37.81	602.67	9° 31′	30 11	10° 06′ 43″	5.651
8 1-2	6° 43′ 59″	56 2 3-4	23 9 3-4	80 0 1-2	40.16	680.35	8° 26′	32 10	9° 31′ 09″	6.005
9	6° 21′ 35″	59 6 1 2	25 2 1-2	84 9	42.51	762.75	7° 31′	34 9 1-4	8° 59′ 30″	6.359
9 1-2	6° 01′ 32″	62 10 1-4	26 7 1-4	89 5 1-2	44.85	849.85	6° 45′	36 8 1-4	8° 31′ 10″	6.713
10	5° 43′ 29″	66 2	28 0	94 2	47.20	941.67	6° 05′	38 7 1 2	8° 05′ 40″	7.067
10 1-2	5° 27′ 09″	69 5 1-2	29 5	98 10 1-2	49.55	1038.19	5° 31′	40 6 1-2	7° 42′ 36″	7.420
11	5° 12′ 18″	72 9 1-4	30 9 3-4	103 7	51.90	1139.42	5° 02′	42 5 3-4	7° 21′ 35″	7.774
11 1-2	4° 58′ 45″	76 1	32 2 1-2	108 3 1-2	54.25	1245.35	4° 36	44 4 3 4	7° 02′ 26″	8.128
12	4° 46′ 19″	79 4 1-2	33 7 1-2	113 0	56.60	1356.00	4° 14′	46 3 3-4	6° 44′ 51″	8.482
12 1 2	4° 34′ 52″	82 8 1-4	35 0 1-4	117 8 1-2	58.95	1471.35	3° 54′	48 3	6° 28′ 40″	8.835
13	4° 24′ 19″	86 0	36 5	122 5	61.30	1591.42	3° 36′	50 2	6° 13′ 43″	9.189

These are all the dimensions required to lay out a turnout, and the special ones needed in actual field use are printed in heavy face type. They are practically true whether the turnout is from a straight line or from the inside or outside of a curve, the only variation being in the degree of curvature, in the last two cases where it is

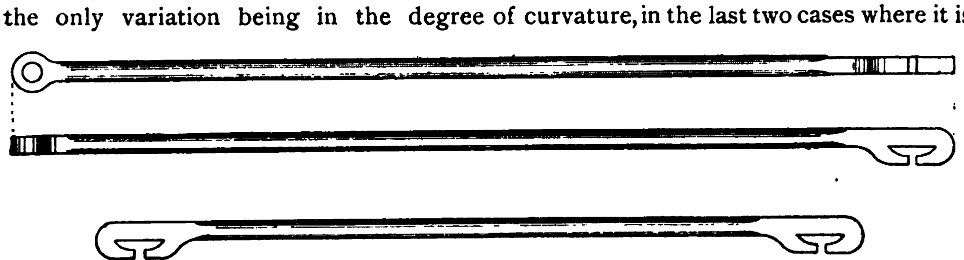
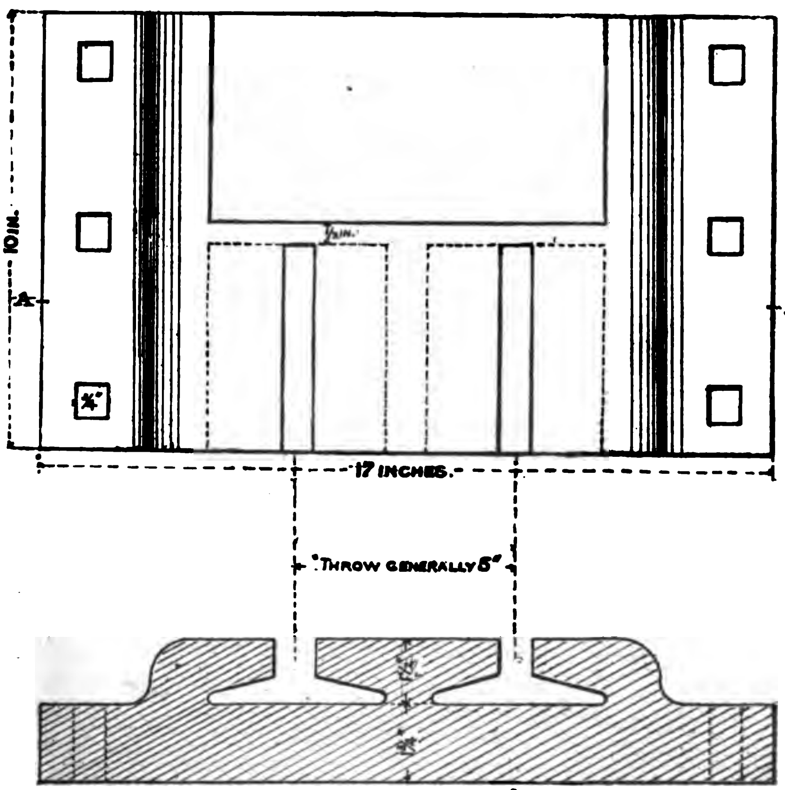


FIG. 57.—CONNECTING RODS.

approximately increased or decreased by the degree of main track curve according as the turnover springs from the inside or outside respectively. Inasmuch as the curves

for ordinary frog numbers are sharp, it should be avoided as much as possible to have the siding come from the inside of a curve.

For the switch rails it is best to use two 30-foot rails in order to be able to spike as much as possible. The unspiked parts are held together by "switch-rods" at least four in number, but better five, and the toe end connected with the switch-stand by a "connecting rod." These rods, Fig. 57, should be made of either 1 5-8 inches round, or 1 1-2 inches square, iron and should weigh about 35 lbs. each for standard gauge. They can be made at the rate of a set of one connecting, and four switch, rods per day's work of one forge. The jaws on switch rods are sometimes punched out from a solid toe, which process, however, does not give as satisfactory results as turning them over by hand. Riveted work is also done, the bar being a strap of at least 2 in. by 5-8 inches, with lugs forming the jaws, riveted on. They are inferior to welded rods. Rod No. 1., which is nearest the head-block, and the connecting rod should be made to fit the base of the rail exactly, without any lost motion whatever, and be promptly changed should it wear loose. The rods back of No. 1, should be made so that the trackmen can drive them on without using force, and to hold the moving rails in exact gauge unless it be a turnout from the inside of a curve where the



CROSS SECTION ON "AB."

FIG. 58.—CAST-IRON HEAD CHAIR.

gauge needs widening. If the switch is subject to hard or fast running, No. 1 rod should be doubled. For if this rod breaks, and it does sometimes, the ends of the moving rails are uncontrolled and an accident is sure to result. The rods toward the heel need not be as large as No. 1, but it is just as well to have one size throughout in

order to avoid keeping several styles on hand, or give some careless trackman the opportunity to put a weak rod where a strong one is required. As all old roads have several patterns of rail in use, the trackmen should be supplied with thin wedges of iron, about 3 inches long, to drive between the edge of the rail base and the jaw, in order to make a tight fit in case they are obliged to use large sized rods on small rails. These wedges, called keys, should be avoided as much as possible, especially on No. 1 rod, except for temporary purposes until the proper sized rods are obtained, as they are liable to drop out and give trouble.

The head block on which the toe of the moving rails rests is a substantial piece of timber about 14 to 16 feet long according to the design of the switch-stand. Its face must be broad to give head-chairs and switch-stands a good bearing, and its thickness sufficient for stiffness. The best dimensions in section are a face of 12 inches and a depth of 8 inches. The head-chairs were formerly always made of cast-iron of general design as in Fig. 58, their weight being about 80 to 90 pounds. In order to diminish weight and give a less refrangible material, malleable iron is substituted for cast-iron, so that the weight is reduced to about 50 pounds for a substantial article. In cold weather, and if the head block gets worn, cast,

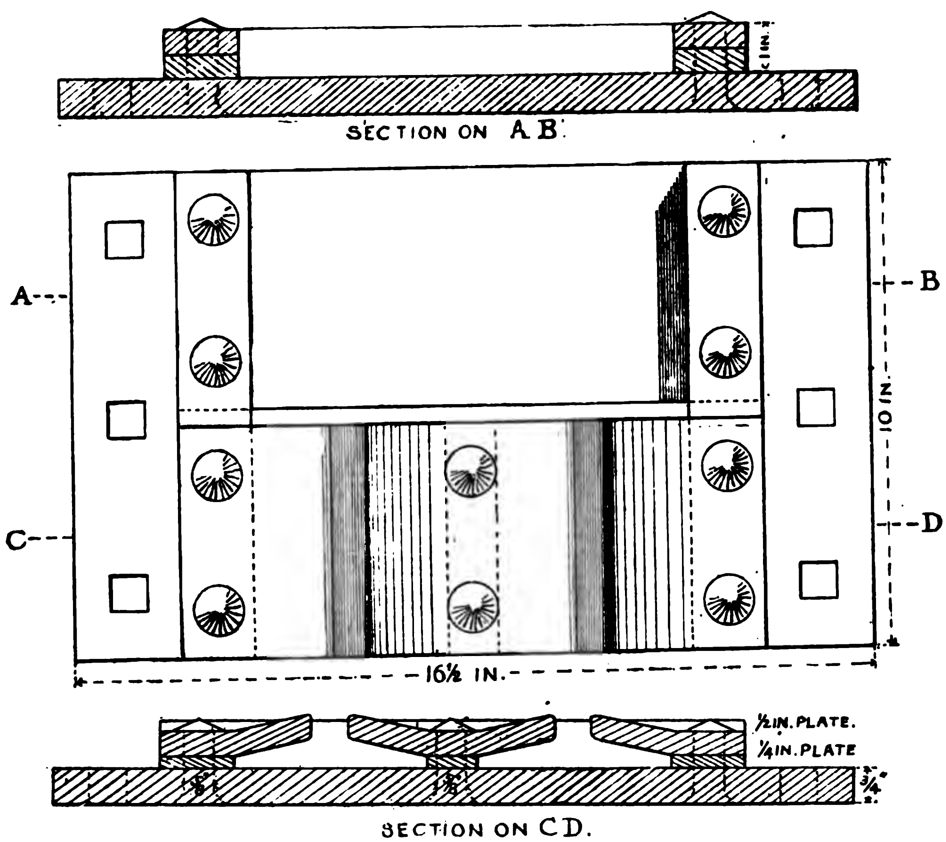


FIG. 59.—WROUGHT-IRON RIVETED HEAD-CHAIR.

and even malleable iron chairs break very easily and are an element of danger and great expense. To prevent this, wrought-iron riveted chairs, Fig. 59, are used. They soon repay their extra prime cost.

A simpler and less expensive chair than this is the design (patent applied for) of

Mr. W. H. Starr, Fig. 60, which can be stamped out by a steam hammer, or even easily rolled. To prevent creeping, the two fixed rails or "stub rails" are bolted together with a cast filler of proper dimensions between them, and fish-plates on the outside, while a wrought-iron stirrup or band 1-8 inch to 1-4 inch thick is put around in front of the rail ends with the double purpose of adding extra security and prevent-

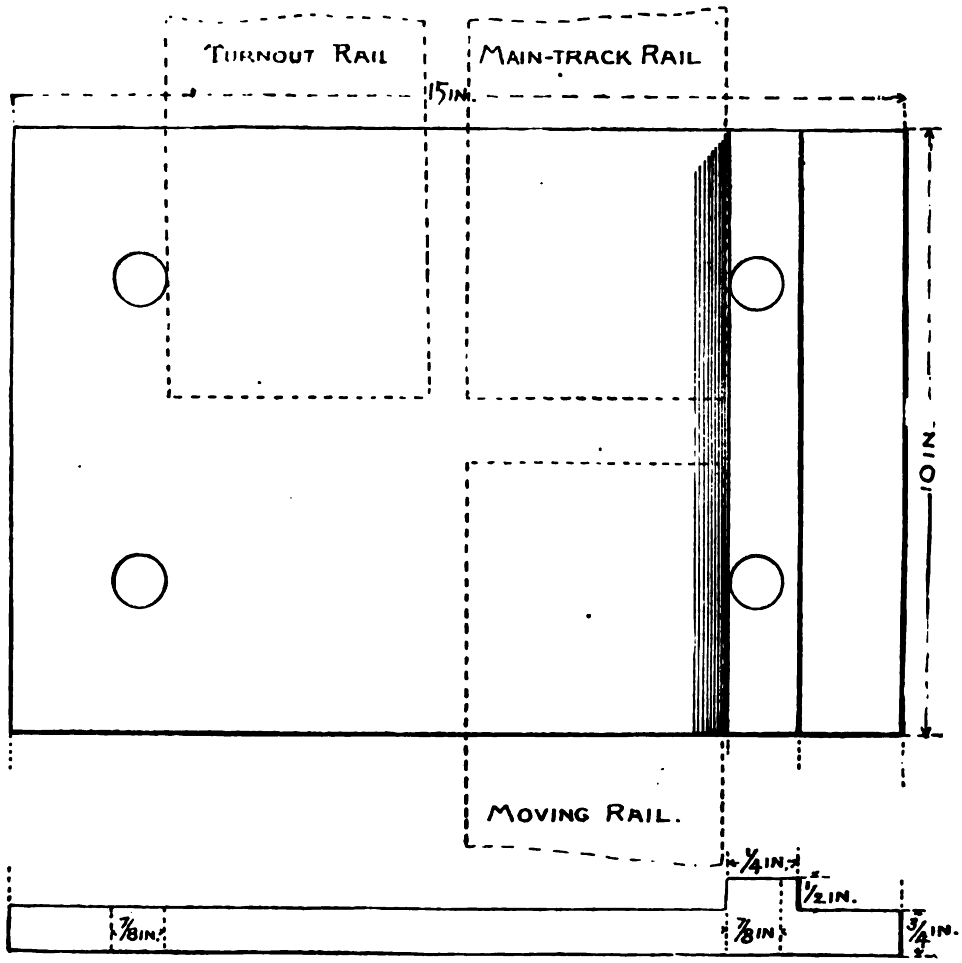


Fig. 60.—Starr's Wrought-iron Head Chair.

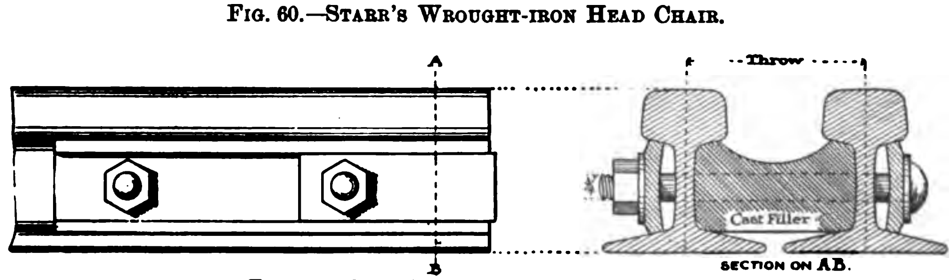


Fig. 61.—Cast Filler for Starr's Chair.

ing the moving rails from catching, should they expand. This arrangement is shown in detail in Fig. 61. Spikes driven through the holes in the plate hold the stub rails firmly. The chair is both right or left, and the dotted lines in the figure show the

position of the rails and how the spike holes are located. Of course these latter are punched to suit the rail base. In use the rib should be on the outside.

The throw of the switch is the distance between the centers of the stub rails and is for standard gauges almost always 5 inches. The distance between the ends of the stub and the moving rail varies with the season. It should be in excess of the width of the dividing partition about 3-4 inch to 1 inch in winter, and 1 inch to 1 1-2 inches in summer. The switch stand, or the apparatus by which the power is applied to throw a switch, also admits of a variety of designs. The old "harp" pattern Fig. 62 is still considerably used, especially on old roads, but it is very awkward and liable to injure a switchman should it hold hard and then suddenly slip.

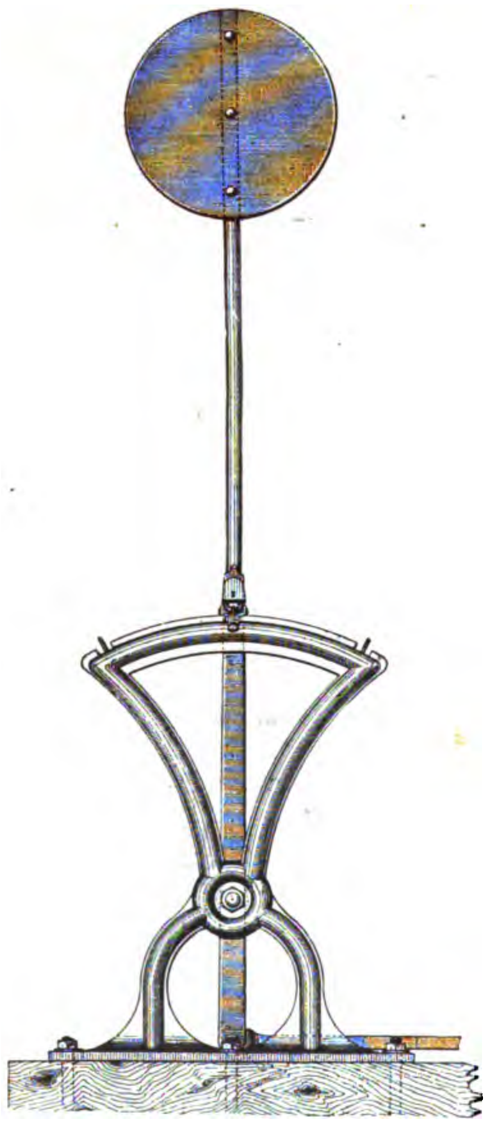


FIG. 62.—HARP SWITCH STAND.

A much better style is shown in the Erie stand, Fig. 63, the frame being of cast-iron and the moving parts of wrought, 212 lbs. of the former and 120 lbs. of the latter in weight. All stands should have a broad, firm base, as considerable force is frequently required to throw a switch, and moreover, constant use soon shakes it loose unless it has a good footing. The "boxes" where the "target-rod" or "standard" is held should be clasped by a wrought-iron band so that in case they break they will not fall out of place. The eye of the connecting rod should fit the pin at the bottom of the "standard" without lost motion. For yard work where it is necessary to put the switch-stands between the tracks, a short form is shown in Fig. 64, in which the cast-iron amounts to 140 lbs. and the wrought to 90 lbs. Even this form at times takes up too much room; or perhaps for unimportant sidings a less expensive style is desired; for which cases the "tumbling-switch" or "ground-lever," Fig. 65, is used, which lies flat on the head block. In winter they have the disadvantage of being covered by snow. Some roads, to obviate the annoyance of the switch-stand being shaken by the jar, attach the target to a post set in the ground entirely independent of the ties, connected by a rod with the moving rails which are thrown by a tumbling-switch, which arrangement is frequently used to elevate the switch targets above ordinary obstructions so that they can be seen at a long distance. Such a design is given in Fig. 66.

Every switch-stand should have a target made of sheet iron to enable the trainmen approaching the switch to see which way it is set. These targets should have two parts at right angles to each other and painted different colors, generally white and red. Signals can be distinguished in three ways; position, shape and color, whose importance is in the order named. If it is possible to see at all, while the color and even the shape of an object may be indistinguishable yet its position can be discerned. On the other hand colors fail to be distinct sooner than shape. With the ordinary switch-stands radical change of position of the targets is difficult and expensive to obtain, therefore the shapes of the two parts, being thus the most distinguishing features, should be made as varied as possible, so that even if the color is obscured by a fog, an engineman can tell by the outline of the target whether or not the switch is set right. In this same connection it is obvious that a perfect uniformity should be preserved over the whole road. The shape of a target admits of an infinite number of designs, many of those seen in common use being very faulty. A very neat shape is shown in the Erie targets, Figs. 63 and 64, or the very similar P. R. R. standard, Fig. 66. The targets, to ensure brightness, should be painted every six months, spring and autumn.

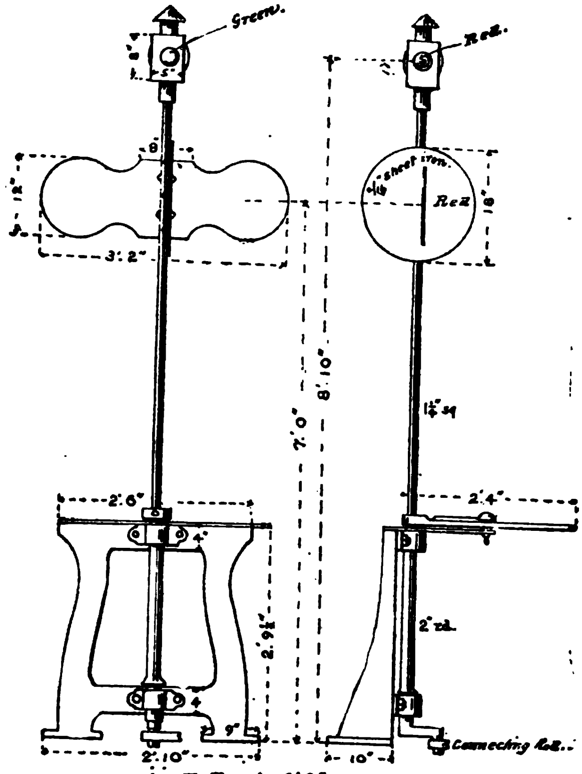


FIG. 63.—HIGH SWITCH-STAND.

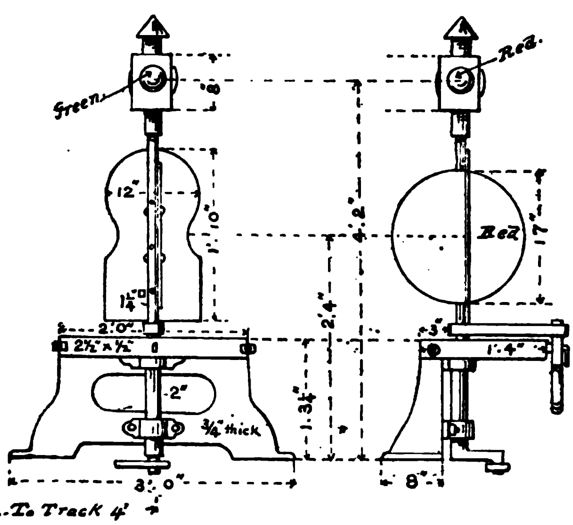


FIG. 64.—LOW SWITCH-STAND.

At night a lamp is fixed on the top of the target standard. These lamps are usually about 6 inches square and 8 to 10 inches high, the former dimension depending on the distance of the lenses which, colored to correspond with the target, are set in opposite sides of the lamp. As a rule, green

at night means the same as white by day, and red answers to its own color. It is not advisable to use white in a signal-lamp owing to the liability of mistaking it for some outside light. Originally plain glass was used in switch-lamps, but later lenses were

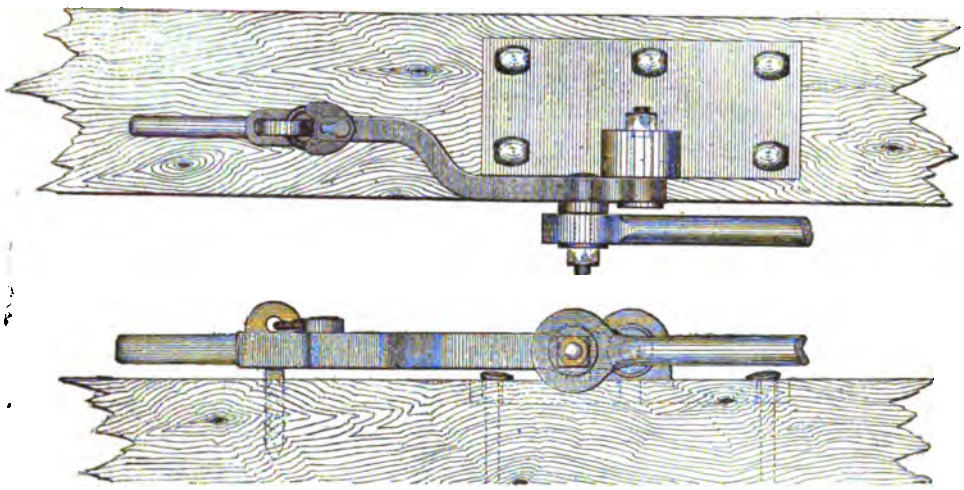


FIG. 65.—"GROUND LEVER," OR "TUMBLING" SWITCH-STAND.

introduced to concentrate the rays. The efficiency of a lens for this purpose depends on its ability, when the flame is placed at the principal focal distance, to concentrate the rays into a parallel beam. This permits the light to be clearly seen at all ranges, and so is proportionally superior to plain glass where the rays of light can pass through in all directions and of which the greater part are entirely lost as they radiate into space.

Fig. 67, represents various styles of lenses. No. 1 is a plano-convex, commonly called a "bull's-eye." Its weight, causing extra expense in first cost and a heavy strain on the lamp-case is objectionable. Nos. 2 and 3 show two patterns of plano-convex corrugated lenses known as "Fresnel" lenses, after the name of the inventor, differing only in the number of rings. This style of lens is very weak and liable to break. Fo. 4 is a concavo-convex lens, commonly called the "Semaphore" lens. Unfortunately for its effectiveness, however, the curvature of the faces is such as to scatter the rays of light rather than to concentrate them into a parallel beam. The object of the corrugation is merely to diminish weight and does not effect the principle of the lens, since the Fresnel is really but an ordinary plano-convex (No. 1) "telescoped." The objection to all these external corrugations is the readiness with which they catch snow and ice in winter and dirt at all times.

The Corning Glass Works have recently perfected a lens called the "Smooth-face Semaphore," a double convex lens shown as No. 5, which is strong, light, and with the corrugations on the inside. Great care was used in its designing so as to render effective all the rays which pass through it. Photometric experiments conducted by the author place their relative effective values as follows:

Smooth-face Semaphore	100.00
Three Ring	70.41
Bull's Eye	67.60
Two Ring	48.73
Semaphore	38.03

The superiority of the smooth-face Semaphore is due to its curved shape which is better able to resist the distortions of contraction in cooling and thus more closely retains the theoretical form than the other styles. But apart from this it is practically

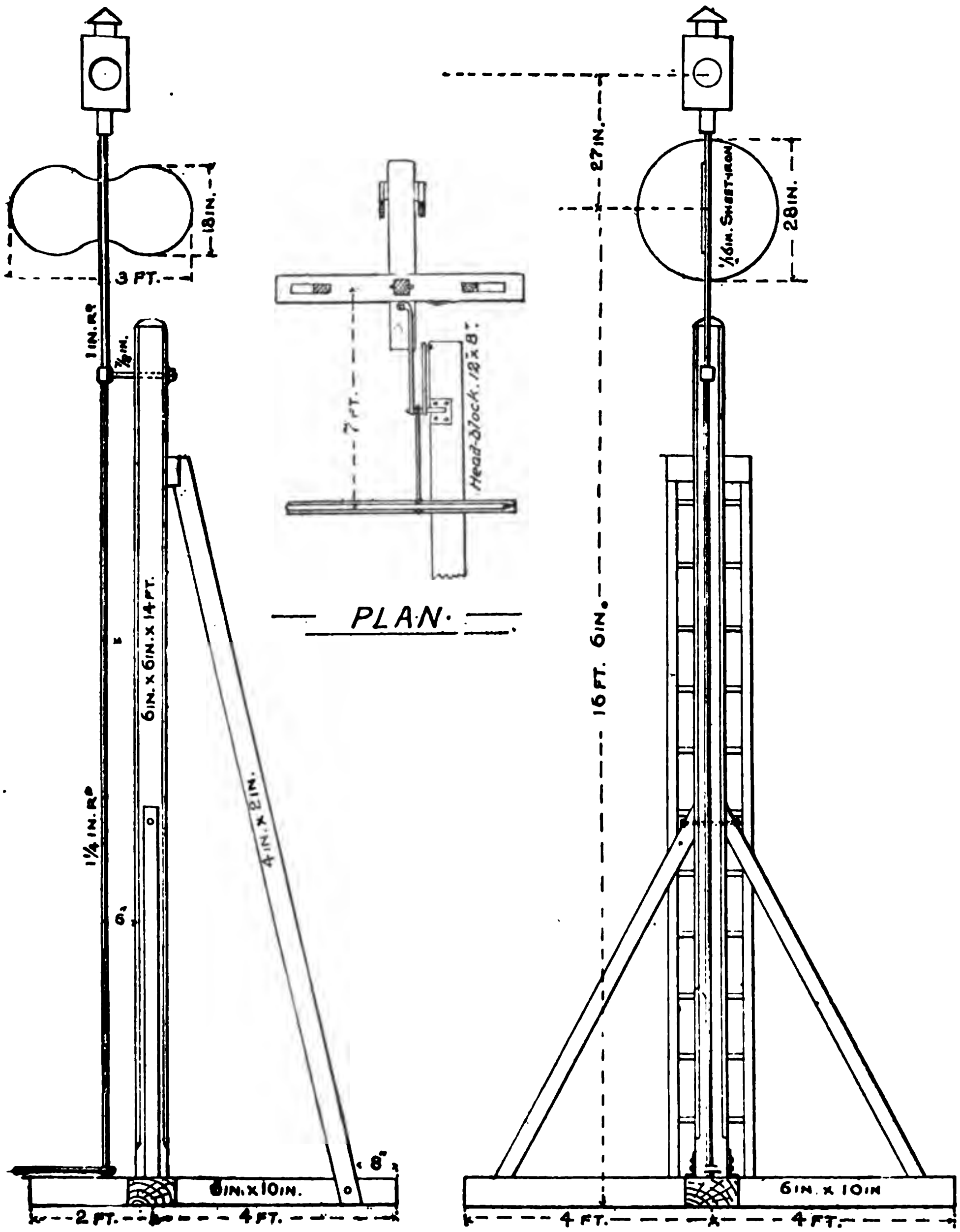


FIG. 66.—EXTRA HIGH SWITCH-STAND.

the best lens offered, as on account of the corrugations being internal they will not catch snow and dirt, and are not liable to be chipped by abrasion.

For single track work a lamp must be provided with four lenses, but on double

track only three are necessary, two red and one green, which latter arrangement gives not only economy in lamp construction but greater simplicity and consequent security. For an engineman sees only those safety signals which are on his track and it is impossible for him to be drawn into danger through being misled by a safety signal on the other track. At times of wreck or other cause, when but one track is used, it is not necessary to provide two green signals. While there is only negative evidence for safety there is positive evidence for danger which is really what is demanded; for if the switch is set *wrong* it will show red *both* ways since there are two lenses of that color in each lamp.

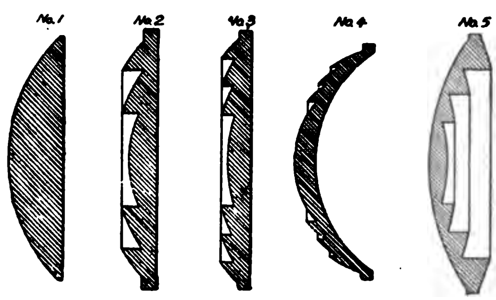


FIG. 67.—CROSS-SECTIONS OF LENSES.

Fig. 68 gives a sectional view of a good design for a switch lamp. The socket, and bottom are made in one casting, to which the sides of the case and a wrought-iron lamp-cup holder are riveted. The best material for the sides is XX tin. The weak point in a switch-lamp is the connection between the case proper and the bottom; the design here given in which no solder is used (but instead the sides are riveted to an angle which is part of the bottom) is simple, strong, durable and cheap. The oil cup which should be big enough to hold a fifteen hours' supply, slides into a groove as shown, an arrangement which prevents its being tipped over or jarred out of place. Ventilation is obtained as indicated by arrows, through holes in the bottom, the force of the wind being thus entirely broken against the bottom of the cup and before it reaches the flame. The top of the standard on which the lamp sets should be made to correspond with the plan of the socket so that the lamp can be set on one way only. The door (not shown in the figure) should not be hinged, but made to slide in guides at the side, which guides should be made as deep as possible so as to prevent any leaky draught from affecting the flame. In order to get the angle to hold the lenses the tin of the sides is swedged out in a mould; a circular collar is then soldered at the back of the lens, and a circular hood of galvanized iron riveted to the casting to afford a stand for the lamp. The other details of the lamp are shown in the figure and a bill of materials and cost is given as follows: Tin, 14″x20″ 2 sheets; Galvanized Iron, 1-4 lb.; Wrought Iron, 1-4 lb.; Cast Iron, 2 lbs., Rivets, 26; Solder, 1-4 lb.; Wire, 1 oz.; Burner, 1; Lenses, 3 or 4; Paint, 1-10 pint; Labor, 3-4 day.

From the head-block both tracks are laid on one set of ties, varying in length according to the turnout curve, and carried to a point beyond the frog where the ordinary cross-ties in each track can be put in without interfering with each other. On account of their length these ties (called switch-ties) are usually of sawed timber of any required dimensions. But our previous remarks on cross-ties apply equally to switch-ties, and therefore hewn timber should be obtained if possible. As to cross-sections, their thickness should be the same as that of the standard cross-tie, and the breadth certainly not less than 8 inches, since the lead rails of frogs in general use are laid to a sharp curve, and there being no elevation, they cut into the ties unless they have a good bearing. On account of the extra expense of handling and putting in place, only the best white oak, or timber capable of giving the longest possible life should be used. The length of these ties depend on the distance between the head-blocks

and the frog as given in Table No. 1. But this distance is governed by the frog-angle or frog-number, which must be explained before proceeding further.

Fig. 69 is an outline diagram of a frog. The angle is the divergence between the two sides of the point, that is, the angle bounded by the two lines *BA* and *AC*, and the number is the ratio of the base *B C* to the perpendicular *A E*, or the number of times the heel of the point is contained in the length, which latter must be measured down the center, and not along one of the sides. The number, therefore, is greater in proportion as the angle is smaller.

For general use Nos. 10, 8 and 6 (or 6 1-2), will be found most convenient. No. 10 is suitable for main-track cross-overs, and all turnouts where trains are liable to run from 10 to 20 miles an hour. Even for this frog number the degree of curvature is over 6°, which, since there is no elevation, is certainly as sharp as is admissible for such rates of speed.

For ordinary turnouts in yards, or where space is limited and no high speed attempted, frog No. 8, whose curve is nearly 10°, answers very well. Then, for some turnouts, where great economy of room is necessary, use No. 6 (or 6 1-2). These three numbers should cover all ordinary cases. For such frogs, spacing the ties 22 1-2 inches between centers beginning from the head-block, which is equivalent to 16 ties to a 30 foot rail, the following switch-ties, Tables 2, 3 and 4, will be required in order to have their ends line up on the turnout side, and project on both sides beyond the outer rail to the same extent as an 8 ft. cross-tie in a single track.

In order to get the lengths required to correspond with a cross-tie of other size than 8 ft., it is only necessary to add to the figures given in the table the difference between the length of the cross-tie in question and 8 ft. If it is inconvenient or not desirable to use timber sawed so accurately, the ties in each set can be readily made into groups according to the nearest half or whole foot. Thus the No. 8 set would become: 3 ties, 8 ft. 6 in. long; 5 at 9 ft.; 4 at 9 ft. 6 in.;

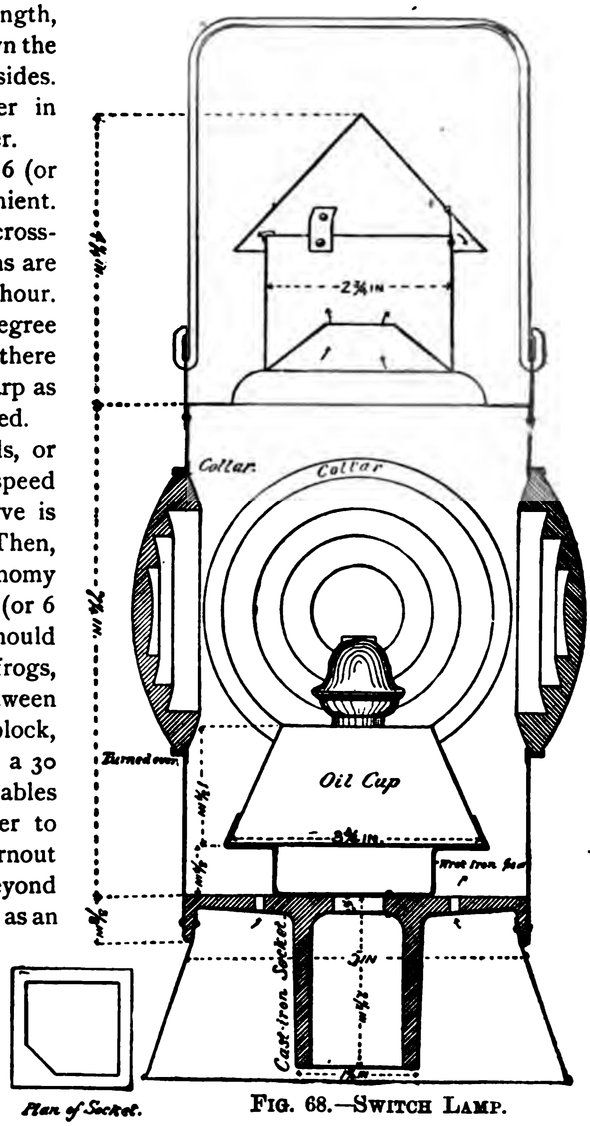


FIG. 68.—SWITCH LAMP.

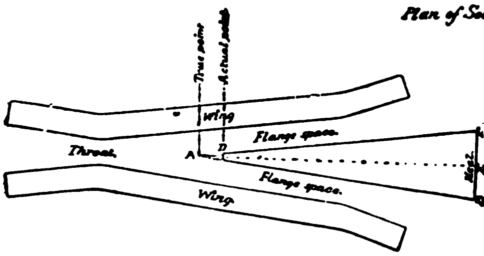


FIG. 69.—OUTLINE DIAGRAM OF FROG.

Bill of Switch-Ties.—Tables, Nos. 2, 3, 4.

Frog No. 8.
$22\frac{1}{2}$-*in. Centers.*

Piece		Length.
1	6″ × 8″ ×	8′ 6″
1	"	8′ 7″
1	"	8′ 8″
1	"	8′ 9″
1	"	8′ 11″
1	"	9′ 0″
1	"	9′ 1″
1	"	9′ 2″
1	"	9′ 4″
1	"	9′ 5″
1	"	9′ 7″
1	"	9′ 8″
1	"	9′ 10″
1	"	10′ 0″
1	"	10′ 2″
1	"	10′ 4″
1	"	10′ 6″
1	"	10′ 8″
1	"	10′ 10″
1	"	11′ 0″
1	"	11′ 2″
1	"	11′ 5″
1	"	11′ 7″
1	"	11′ 10″
1	"	12′ 0″
1	"	12′ 3″
1	"	12′ 6″
1	"	12′ 8″
1	"	12′ 11″
1	"	13′ 2″
1	"	13′ 5″
1	"	13′ 8″
1	"	13′ 11″
1	"	14′ 1″
1	"	14′ 4″
1	"	14′ 7″
1	"	14′ 10″
1	"	15′ 1″
1	"	15′ 3″
1	"	15′ 6″
1	"	15′ 9″
1	"	16′ 0″
42 pieces.		489′ 11″ lin. 1959.7 ft. B. M.

Table No. 3.

Frog No. 10.
$22\frac{1}{2}$-*in. Centers.*

Piece.		Length.
2	6″ × 8″ ×	8′ 6″
1	"	8′ 7″
1	"	8′ 8″
1	"	8′ 9″
1	"	8′ 10″
1	"	8′ 11″
1	"	9′ 0″
1	"	9′ 1″
1	"	9′ 2″
1	"	9′ 3″
1	"	9′ 4″
1	"	9′ 6″
1	"	9′ 7″
1	"	9′ 8″
1	"	9′ 10″
1	"	9′ 11″
1	"	10′ 0″
1	"	10′ 2″
1	"	10′ 3″
1	"	10′ 5″
1	"	10′ 7″
1	"	10′ 8″
1	"	10′ 10″
1	"	11′ 0″
1	"	11′ 2″
1	"	11′ 4″
1	"	11′ 5″
1	"	11′ 7″
1	"	11′ 9″
1	"	12′ 0″
1	"	12′ 2″
1	"	12′ 4″
1	"	12′ 6″
1	"	12′ 8″
1	"	12′ 10″
1	"	13′ 1″
1	"	13′ 3″
1	"	13′ 5″
1	"	13′ 7″
1	"	13′ 10″
1	"	14′ 0″
1	"	14′ 2″
1	"	14′ 4″
1	"	14′ 7″
1	"	14′ 9″
1	"	14′ 11″
1	"	15′ 1″
1	"	15′ 4″
1	"	15′ 6″
1	"	15′ 8″
1	"	15′ 10″
1	"	16′ 0″
52 pieces.		618′.1″ lin. =2472.8 ft. B. M

Table No. 2.

Frog No. 6.
$22\frac{1}{2}$-*in. Centers.*

Piece.		Length.
1	6″ × 8″ ×	8′ 6″
1	"	8′ 8″
1	"	8′ 9″
1	"	8′ 11″
1	"	9′ 1″
1	"	9′ 2″
1	"	9′ 4″
1	"	9′ 6″
1	"	9′ 8″
1	"	9′ 11″
1	"	10′ 1″
1	"	10′ 4″
1	"	10′ 6″
1	"	10′ 9″
1	"	11′ 0″
1	"	11′ 3″
1	"	11′ 6″
1	"	11′ 10″
1	"	12′ 1″
1	"	12′ 5″
1	"	12′ 9″
1	"	13′ 0″
1	"	13′ 4″
1	"	13′ 8″
1	"	14′ 0″
1	"	14′ 4″
1	"	14′ 7″
1	"	14′ 11″
1	"	15′ 3″
1	"	15′ 7″
1	"	15′ 10″
31		360′.6″ lin. =1412 ft. B.M.

Table No. 4.

3 each, at 10 ft., 10 ft., 6 in., 11 ft. and 11 ft. 6 in. respectively; and 2 at every 6 in. from 12 ft. to 16 ft. inclusive.

Fig. 70 gives a complete plan for a No. 8 turnout, showing moving rails, switch-rods, head-block, spacing of switch-ties, location of frogs, guard-rails, ordinates, etc. It will be noticed that in these plans the distance from center of head-block to frog-point is given as 53 ft. 3 in., while table No. 1. puts it at 52ft. 11 in. This difference is due to the bluntness of the frog-point. The table is calculated to the "true" point, while in practice we have to measure to the "actual" point. (See frog diagram.) This bluntness is generally 1-2 inch, so that the distance between the true and the actual points of a No. 8 frog, is 4 inches. Sometimes, however, instead of these long ties, the ordinary switch-ties doubled in past each other, as in Fig. 71, are used. This practice, except for temporary purposes, is to be avoided. It is a waste of material, and it is impossible to get satisfactory results with the tamping when they are so close together.

Distance between Frog Points on Crossovers.

Frog Number.	Distances between Tracks.					
	ft. 7	ft. in. 7 6	ft. 8	ft. in. 8 3½	ft. in. 8 6	ft. 9
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft in.
6	13 3¼	16 3	19 2¾	20 11⅛	22 2⅜	25 2⅜
6½	14 5⅜	17 8¼	20 11	22 9⅜	24 1⅜	27 4⅜
7	15 7⅜	19 1¼	22 7	24 7⅛	26 1	29 6⅜
7½	16 9½	20 6⅛	24 3⅜	25 5¼	28 0	31 8⅜
8	17 11¾	21 11⅛	25 11¼	28 3⅜	29 11	33 10⅜
8½	19 1⅜	23 4½	27 7¼	30 1	31 10	36 1
9	20 3⅜	24 9⅛	29 3¼	31 10⅜	33 9¼	38 3
9½	21 5¾	26 2⅛	30 11¼	33 8½	35 8¼	40 5
10	22 7⅜	27 7⅛	32 7¼	35 6¼	37 7	42 7
10½	23 9⅜	29 0¼	34 3¼	37 3⅜	39 6	44 9
11	24 11¼	30 5¼	35 11	39 1⅜	41 5	46 10⅜
11½	26 1¼	31 10	37 7	40 11¼	43 3¾	49 0⅜
12	27 3	33 3	39 2⅜	42 8⅜	45 2¼	51 2⅛
12½	28 5	34 7¾	40 10¾	44 6⅜	47 1½	53 4⅜
13	29 7	36 0¾	42 6¾	46 4	49 0½	54 6⅛

Table No. 5.

Fig. 72 shows a plan of a double turnout or a "three-throw" switch with No. 8 frogs. In order to find the lengths of the switch-ties for such a case, the rule

is, to double the length of each tie in a "single turnout" set and subtract the length of the standard cross-tie. Where the lead rails cross, another frog is required which is called the "crotch-frog." The proper angle for the crotch-frog and distance from the head-block is given in table No. 1. Sometimes the principal frogs are of different angles instead of being equal. In this event to obtain the set of switch-ties, the lengths of the respective ties in the two sets corresponding to the two frogs are to be added together and from their sum the length of the standard cross-tie is to be subtracted. Three-throw switches are used in yards or places where space is limited; otherwise they are not desirable on account of difficulty of maintenance.

A cross-over is simply a combination of a turnout in each of two parallel tracks with a connecting piece between them. Each turnout is to be laid out according to Table 1. The frogs must be of the same angle. Table No. 5 gives the distances between the frog points, which distances are to be measured on the parallel tracks.

If the parallel tracks are straight the connecting piece between the frogs is also straight, but if the former are curved it is necessary to curve the cross-over. But, in all cases, whether straight or not, the distances given in the table are correct. Opposite each frog as shown in the plans is a guard-rail in order to guide the wheel flanges and not allow

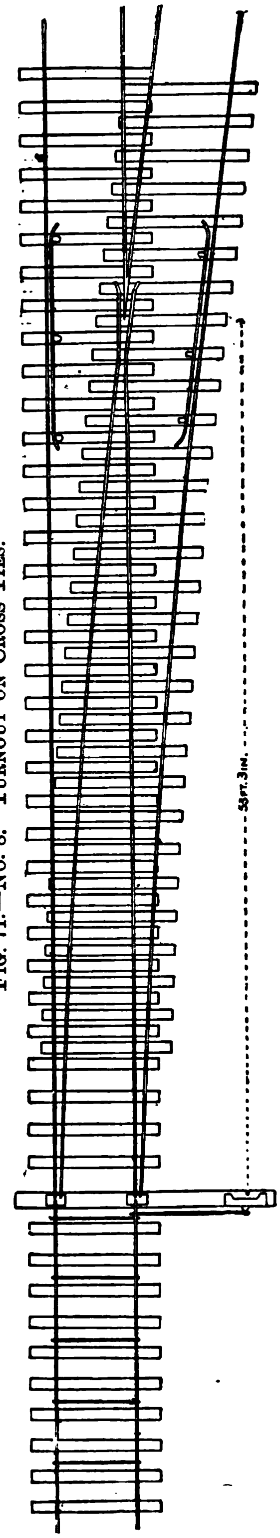


FIG. 71.—NO. 8. TURNOUT ON CROSS-TIES.

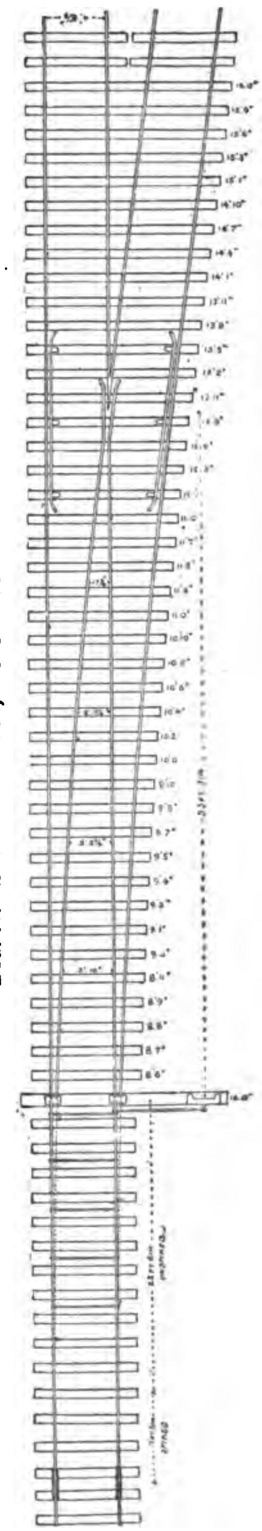


FIG. 70.—SINGLE TURNOUT, NO. 8 FROG.

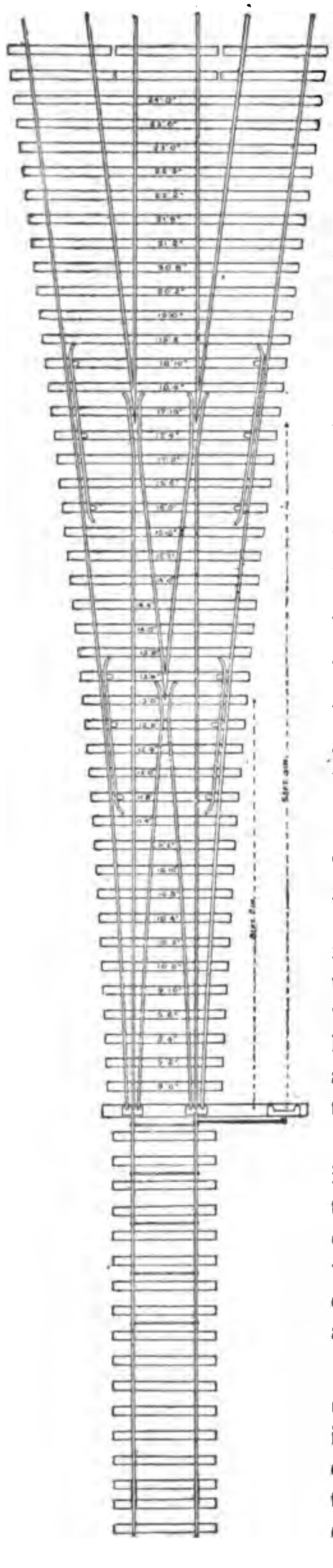


FIG. 72.—DOUBLE TURNOUT. NO. 8 FROG.

them to strike or mount the point of the frog.

A guard-rail should be about 15 feet long and have the flange on one side trimmed off so that it can be set up against the spikes and give 2 inches clearance between the head and the gauge side of the track-rail. If the space is over 2 inches, wheels are liable to hit the frog point. The ends of the guard-rail for a distance of one foot should be turned up in the blacksmith's shop so that they will be four inches out of line or else the rail should be slightly curved so as to give correct space at center and gradually widen to the ends. The rail should be thoroughly well secured by spikes and three knee braces (previously illustrated) placed one at each end, just behind the turn and one in the middle. Avoid using clamps or bolts for this purpose and above all the very bad practice of bracing the guard-rail by a plank between it and the frog. It throws a side strain where none should be thrown, that is, on the frog; it also forms a fulcrum for the guard-rail to rock on and is at best, a make-shift. Sufficient care is seldom given to guard-rails, they being either loose or too wide, the latter especially, as trackmen usually put them in by so many fingers' width of clearance—a most variable gauge.

When the side of a frog point shows signs of wear it is due nine times out of ten to a too great space between the guard-rail and track-rail. Some day a sharp flanged wheel comes along, mounts the frog point and in the wreck which ensues the track is torn up and the cause is assigned as "wide gauge truck," "broken frog," or most probably "unknown," while the work of a few minutes of a track gang on the guard-rail would have prevented the occurrence.

Referring to Fig. 69, we will take up in detail the important subject of frogs. As previously stated, this figure is but an outline diagram with the names of the several parts, and shows how the two flange ways cross. The determining factor is the angle and dependent on it is the frog number as explained above.

A is the "true point" where the sides *A C* and *A B* (prolonged from *D*) meet; but on account of the impossibility of maintaining such a weak fine drawn edge, the end is cut off so as to give in general custom a width of 1–2 inch. This is the "actual point" of practice.

The part *C D B* is properly known as the tongue, although the name "point" is frequently extended so as to include the whole of the tongue, but the two names will be always kept separate in what follows.

The base *B C* of the tongue is called the "heel." The side pieces on which the wheel treads rest till they get so far past the point as to be carried by the tongue, are called "wings." The passage between the wings and the point is called the "flange space," and that part where the wings approach closest together and become tangent to the line of the sides of the tongue prolonged, is called the "throat." The width of the throat should be the same as the flange space.

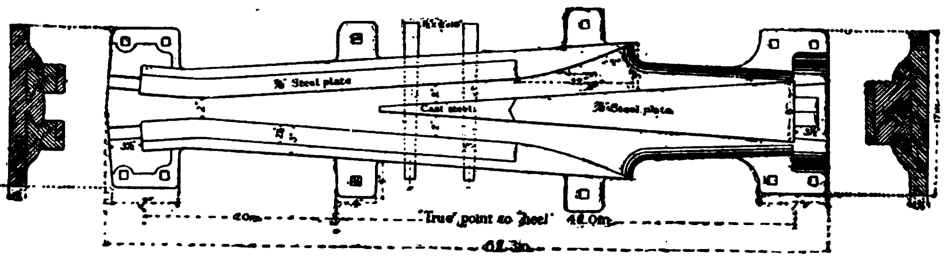


FIG. 73.—CAST-IRON FROG.

The earliest and simplest form of a frog was a pivoted or hinged rail, but the oldest style properly so-called is the cast-iron frog, Fig. 73, at present found only on the older roads and which is fast dying out.

At first the whole frog was of cast-iron, but later, while the main portion was of that material, the wings where subject to wear, and the rear portion of the tongue, were covered with a steel-plate 3-4 to 1 inch in thickness, while the "point," (for such it was called,) was made of cast-steel, fitted into the recess of the casting and held there by two taper keys. The heel of this solid steel "point" was dovetailed to fit the main casting. The rails joining the frog were connected to it by being held in recesses or lugs at the ends. The size of the casting was arbitrary, but on account of the weight was made no longer than necessary, and the general practice was about 6 feet long for a No. 8, which then would weigh in the neighborhood of 800 pounds. These frogs were made before the custom of numbering was introduced, and were designated by letters *A A*, *A*, *B*, *C*, whose angles are respectively $5^\circ 15'$, $7^\circ 10'$, $8^\circ 30'$ and $9^\circ 45'$, so that they correspond approximately to frog numbers 11, 8 (exactly), 6 3-4 and 6, In addition to its weight there are many decided objections to this form of frog. Since the rails fitted into recesses, in itself a highly objectionable and loose contrivance, the frog had to be let into the ties in order to bring the bottom of these recesses down to the level of the base of the rail. The nature of the material made the frog necessarily rigid and unyielding, and consequently unpleasant to ride over, which qualities combined with lack of tenacity soon resulted, especially when the ground is frozen hard, in its own destruction. The ties supporting such a frog should be 8 inches thick and 10 inches face and placed under the projections intended for the spikes. To provide elasticity the Mansfield and other similar frogs were designed by introducing rubber as a cushion, but the successful production of steel rails opened an entirely new field in the manufacture of frogs. At present frogs, which are always made of steel rail held together by a variety of devices, may be divided into two classes: "stiff" in which the tongue and wings are rigidly connected; and "spring" where the parts are movable and controlled by a

spring. These two classes are again subdivided into three each, "plate," "bolted" and "keyed" according to the mode of fastening. Fig. 74 shows a stiff plate frog where the rails are firmly riveted to an iron plate. In describing this frog in detail there are several items which obviously apply to frogs of every pattern, and hence will not

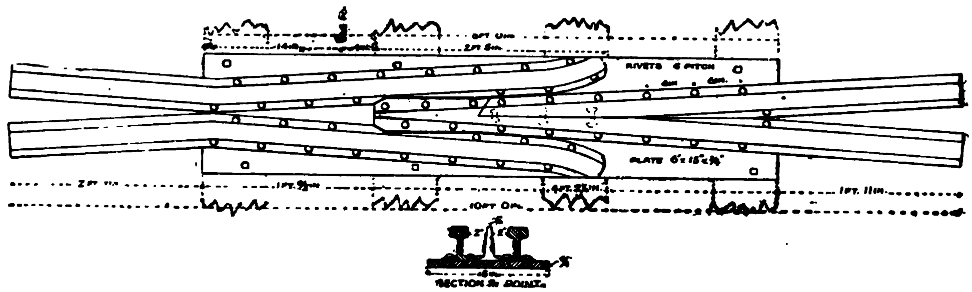


FIG. 74.—PLATE OR RIVETED FROG.

be repeated. The rails which form the tongue should be dovetailed together as shown in the figure to the extent of 3-4 inch at least.

Each rail is to fit the other, and then they are securely joined by three rivets through the web, after which the sides of the head are planed down to form the point. Some manufacturers instead of dovetailing continue the sides of one rail straight, and bevel the other rail off to fit against it, making a very weak joint unless the frog angle is very large. In order to strengthen the tongue at the point, a piece of flat iron 6 to 10 inches long should be welded against the web between the head and base; old fish-plates will answer. This should be done before planing so that the section of the point is V-shaped as the cross-sectional view indicates. Wing rails are bent into shape, and if it is necessary to do this or any other operation in frog manufacture by heat it should be done at as low a temperature as possible, although heating should be avoided if possible since it destroys the temper. The foot of the point should be broad, therefore as much as possible of the rail bases should be left and the base of the wing rails cut away to receive them as shown. An entrant-angle like this should be obtuse or round, as acuteness has a tendency to continue in the shape of a crack. The plate should be long enough to securely hold the parts, and in width contracted as much as possible in order to allow tamping bars to go under it. In thickness it should be stout so as not to bend and have sufficient material to allow the rivet holes on the under side to be counter-sunk, 3-4 inch being found to answer best. To this plate the rails are riveted with 3-4 inch rivets having about 6 inches pitch and the heads on the bottom counter-sunk.

All rivet-holes, both in plate and rails, should be carefully drilled according to template, so that the sides of the tongue will line exactly with the rails beyond the throat. The total length of the frog should at least be great enough to permit angle-plates to be used in connecting it with the track, since a long frog well secured rides better than a short one, a quality which materially prolongs its life. The general dimensions, as given in Fig. 74, are recommended.

In placing a plate-frog in the track it is not necessary to cut the ties down the thickness of the plate although it is commonly done; it is better to let the weight spring the ties half this thickness, and as the jar is sure to settle the frog 3-8 inch, it must always be tamped high to meet this settling. The ties under a plate-frog should

be placed as indicated in the figure. "Hollow" tires bear on the wing rails opposite the point, and here it is that all frogs wear first, and when a riveted frog breaks it is usually at this place. A hollow tired wheel is one where the tread at the part where it is usually in contact with the rail has been worn down so that the outer rim projects in the same manner as the flange on the other side.

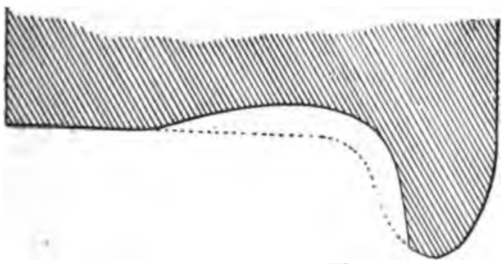


FIG. 75.—SECTION OF WORN WHEEL TREAD.

Fig. 75 shows a hollow tire and a sharp flange, both being the result of wear, the dotted line representing the original surface. In passing over a wing rail of a frog it is plain to be seen how such a wheel is carried entirely by the outer rim. If it were not for such wheels the life of a frog would be as long as that of a rail; it is, therefore, important to watch all wheels and remove them as soon as the tread becomes too much worn.

In order to present a lighter frog with the same elasticity as an ordinary rail, resting directly on the ties, and permitting the worn-out portions to be replaced in the track, the bolted frog was invented, whose details of construction vary slightly with different makers, but of which Fig. 76 is a good sample. The tongue and wing

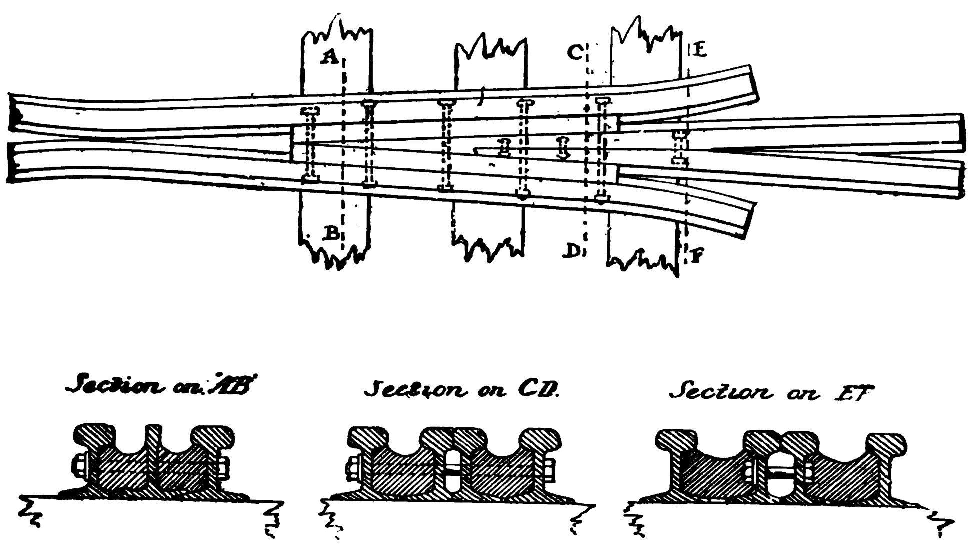


FIG. 76.—BOLTED FROG.

rails are made in the same manner as those of a riveted frog, but are held together by long bolts passing through the webs and are separated by cast-iron "fillers." All the above claimed advantages are certainly gained, but are more than balanced by the accompanying disadvantages of this pattern. The bolts will work loose and hence need constant watching. That side which is exposed to the greatest traffic cuts down into the ties so that the surface of the frog is warped, and then the fillers of cast-iron break. When this happens the tongue generally breaks at the dovetail joint and then the frog is decidedly unsafe. In warm weather, when the joints back of the frog

were tight, the writer has seen all the bolts sheared off by the pressure due to the expansion of the rails. As in the case of the plate frog so here it is recommended to put a tie under the point.

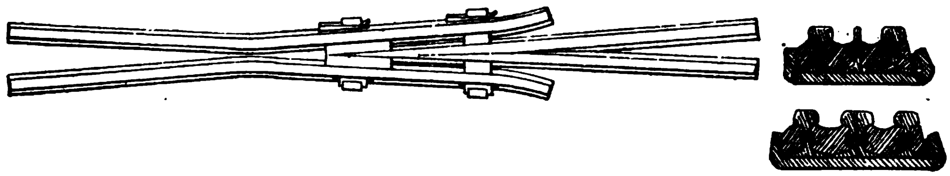


FIG. 77.--PENNSYLVANIA STEEL CO'S. KEYED FROG.

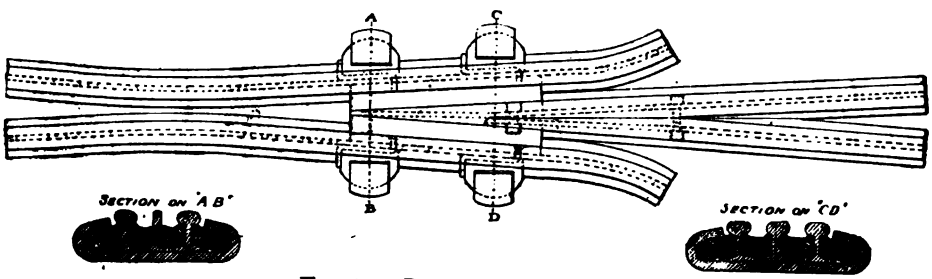


FIG. 77.—RAMAPO KEYED FROG.

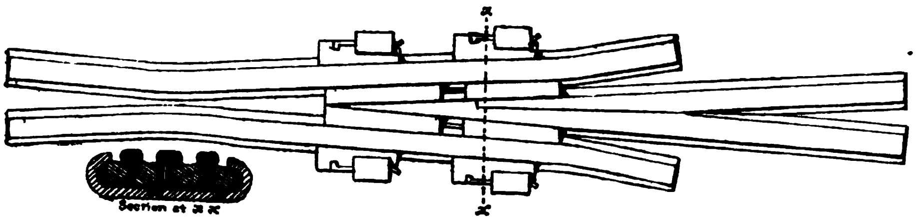


FIG. 77.--BRAHN'S KEYED FROG.

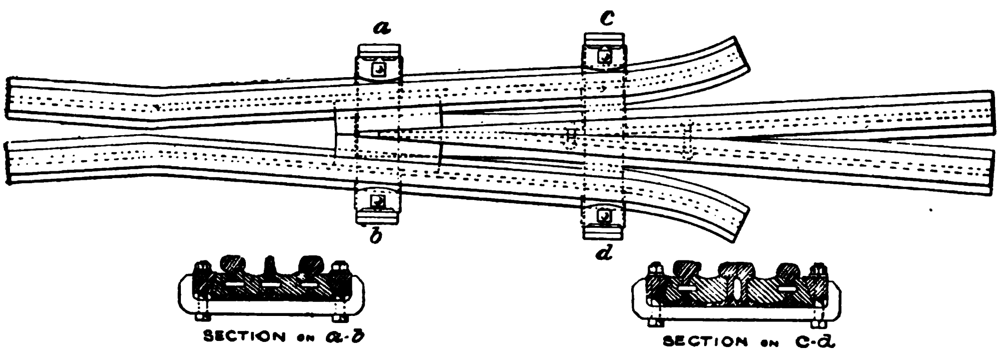


FIG. 77.—UNION S. AND S. CO'S. FROG WITH VERTICAL KEYS.

To obviate these difficulties and give stronger connections the "keyed-frog" was designed, the parts of which are held together by clamps, and keys or wedges, and as they open a larger field for difference in construction four styles of recognized merit are presented in Fig. 77. The previous objection to bolts is done away with, the keys staying set better than nuts, and should they become loose they are readily driven tight by a blow of the trackwalker's hammer. Since the points are held up by the yoke one tie should be placed under the dovetail. The general dimensions given for the plate frog in Fig. 74 are recommended for all patterns of stiff frogs.

As to relative merits the writer prefers first the "plate," then the "keyed," and lastly the "bolted" style, which latter, however, the writer does not deem reliable. Against the first named there are urged loose rivets, extra weight of the plate, necessity of sending the frog to the shop for repairs and too much rigidity. On the other hand, it needs no extra attention, a great advantage on roads with a limited force, for even if the rivets become loose they do not affect the safety of travel, and should the frog break each part is secured and held safely until a new one replaces it. The advantage of being able to change any one part is more imaginary than real: For generally, when the wing rails, which as was said before are the first to wear, need replacing the point will be too much worn for new wings. The frog bears evenly on the ties.

Keyed frogs are very convenient, easy to handle, and when in good condition and the keys kept tight, do not rattle. But they have the objection previously mentioned in connection with bolted frogs, that the side subjected to the greatest traffic cuts into the ties, especially when they are old, giving the frog a twist, producing great strain on the connections so that they are liable to break or become loose, and to require extra attention. A broken wing, rail or tongue is a more serious matter with a keyed than with a plate frog. The objections to the bolted pattern have been given.

The objection to all stiff frogs is the jolt received when riding over them. The wings being worn down, a true wheel must drop into the depression and be suddenly raised by the point, an operation hurtful both to rolling stock and frog. To meet this and always give an unbroken bearing the spring rail frog was devised, of which Fig. 78 shows two styles, the Plate and Keyed as manufactured by the Pennsylvania Steel Co.

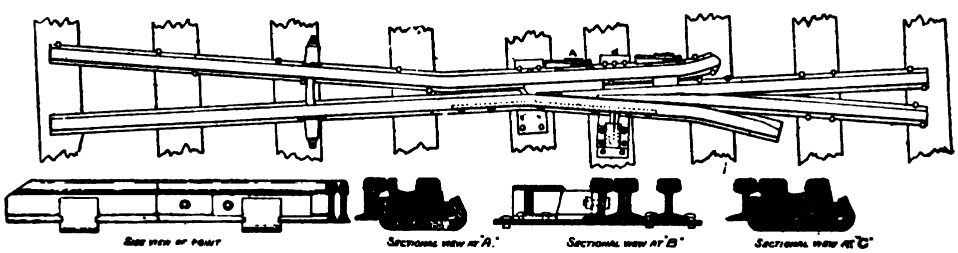


FIG. 78.—PENNSYLVANIA STEEL CO'S. KEYED SPRING FROG.

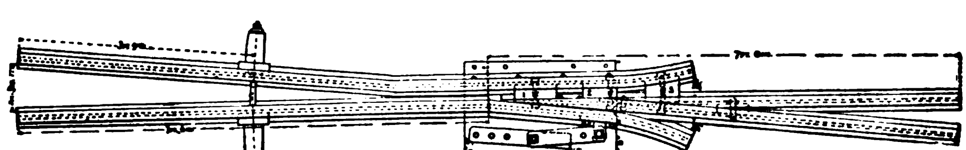


FIG. 78.—PENNSYLVANIA STEEL CO'S. PLATE SPRING FROG.

An examination of this figure shows but one of the wings held fast to the tongue, the other is connected to it by a spring contained in the cup-shaped covers shown in the diagram. The movable or spring rail is part of the main track, and lying as it does close to the frog point, gives the wheels rolling over it an even and unbroken bearing, the same as by an ordinary rail. When the frog is used on the turnout side with a facing switch, the whole flange striking the movable rail near the throat simply crowds it to one side sufficiently to let them pass through, and when this is done the rail springs back to its normal condition. In precisely the same manner, when approach-

ing from the opposite direction or trailing, the flange meets the curved end of the wing and again forces the spring rail as before. Such a frog is very much easier on rolling stock than the stiff patterns are, and since its life is dependent on the severity of the pounding, it is consequently more durable both in point of wear and ability to remain in surface. Of the two patterns, plate or keyed spring frogs, the writer prefers the keyed. The reasons previously enumerated as making the stiff riveted frog superior are not of the same importance when dealing with spring frogs. The jar being absent the parts do not work loose, but the plate catches snow and dirt, and tends to destroy the ease of movement. The writer would, therefore, recommend for all main track work spring rail frogs, and for secondary sidings and yards a stiff plate frog as being cheaper, and also capable of construction and repair in the company's own works. Further examination of Fig. 78 shows that the wing of the spring rail in the keyed frog is longer than the wing of the fixed rail. Formerly both the wings, as shown in the plate frog, were made the same length, but this renders an accident possible to a "hollow tire" or "double flanged" wheel trailing through. When the wheel reaches a place where the worn channel is wider than the tongue it drops down, bringing the outside flange lower than the wing. Sometimes it will climb up the rail and go over all right, at others it will force the spring rail entirely out of place and drop off the point. By prolonging the wing the outside of the tread is caught and a bearing given before the operation described can take place. A stop is also added to keep the spring rail from being pushed too far.

Crossing frogs are used when two tracks cross each other instead of when one track branches out from another. In a crossing there are four frogs to each track, of which two are "single pointed," that is, similar to turnout frogs, and two are "double pointed," as shown in the general diagram of a crossing, Fig. 79.

The general construction of crossing frogs is similar to that of the frogs already described, the angles usually determining the details, and they are made keyed, bolted or plate according to preference. Fig. 79 also indicates two styles of guard rails. When the angle of the crossing is large, say over 45°, it is common practice to have an inner rail running all around the crossing to serve as a guard rail and to give extra stiffness, separated from the main rail by fillers of cast or wrought-iron, preferably the latter. Such an arrangement is shown in the upper half of the diagram. As the angle decreases, in order to economize rail, small guard rails are attached to each of the double pointed frogs as indicated in the lower half of the plan. It was previously recommended to dovetail the rail forming the tongue, but with crossing frogs, as the angle increases, it is more satisfactory to unite them on a level and finally to butt one against the side of the other. Some manufacturers make the whole crossing solid, that is, no joints in the sides between the frogs. While such a design adds stiffness it necessitates the taking up of the whole set in case one frog needs repairing. It is decidedly better to have one joint in each side so that the frogs are independent of each other. As the angle approaches 90° the wear of the frogs and the jolt consequently increases, because at wide angles the wheel drops into the flanged space of the other road, the tread failing to bear on the tongue and wing rail at the same time.

On account of this increased hammering received from two directions the life of a crossing frog is much less than that of a turnout frog. When one of the roads is double tracked it is difficult to keep the frogs in line owing to the running or creeping of the rails on the double line in opposite directions. In case both roads are

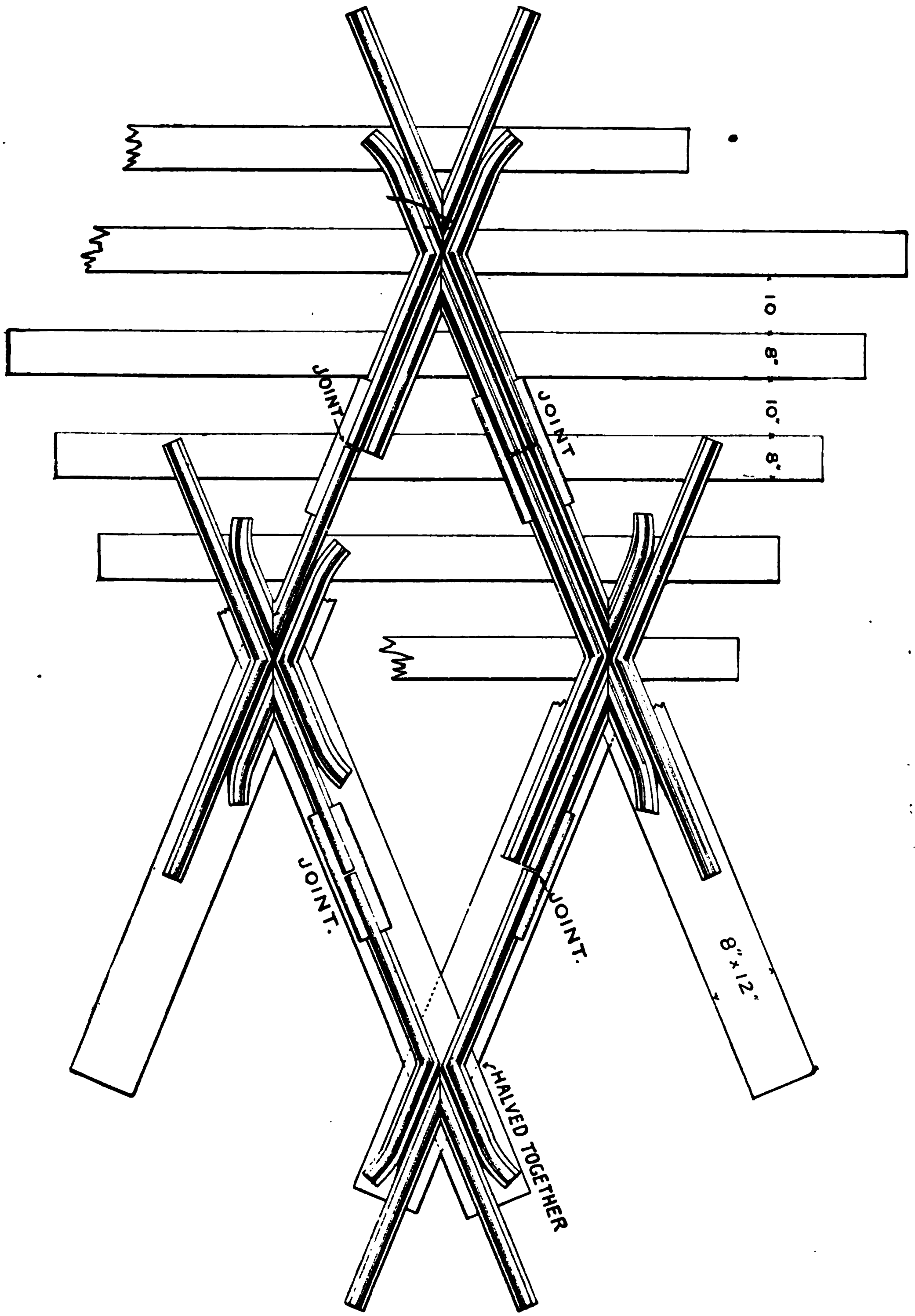


FIG. 79.—CROSSING FROG, SHOWING TWO METHODS OF CONSTRUCTION, AND TWO STYLES OF SUPPORT.

double tracked this disarranging tendency and effect is mutual. There are two systems of support, either by long ties, or by sills, that is, heavy timbers framed together according to the angle, and the crossing spiked down on them. The determining of which is the better depends principally on the ballast, and secondly on the angle.

The heavier timbers, laid deeper in the ground than the cross ties (provided these are 6 inches thick), are less affected by the frost. For this reason, if the ballast is poor it is better to use long ties, but if good, so that there is no heaving, the framed timbers are preferable as affording better support and greater lateral stiffness to resist the tendency to work out of line. With single track, when the angle is less than 45° or closely approaching 90°, it is very convenient to use long ties as being more easily tamped and replaced, and with great angles and very small ones giving good satisfaction.

In the latter case place them so that they are symmetrical with both tracks, that is perpendicular with the line bisecting the angle; while in the other case place them in the regular line of the track with the principal traffic. With double track it is decidedly better to use the framed sets. Fig. 79 shows both systems of support. In all cases, but especially where the sills are used, there should be a generous depth of good ballast underneath not only the crossing itself, but also under both tracks adjacent.

In general custom the word switch is used to designate the whole of the side track from the head-block to the end. Properly speaking, the whole should be called the "side track" or "siding," the special part from the head-block to the frog should be called the "turnout," and the device for passing from the main track rails the "switch." In such sense the author has used the three words and will so continue throughout these pages.

In what has gone before, the "stub-switch" operating through moving rails, has been the only one described, as it more distinctly illustrates the general principle, and is in common use everywhere. The stub-switch, however, has two vital defects, first of which is want of safety. If used as a trailing switch and is misplaced, derailment must ensue by the wheels dropping off the ends of the rails, and carefully kept statistics show, that of derailments 50 per cent. were caused by the defects of stub-switches or their misplacement.

Even if a stub-switch is correctly set the possibility of throwing a wheel from the track is still considerable, for should rod No. 1, or the connecting rod break or wear loose (as they do and rapidly too), the ends of the moving rails are not rigidly controlled, and a wheel with a sharp flange is liable to mount the end of the stub rail, and sometimes flanges are so sharp as to need only 1-4 to 1-2 inch play of the moving rails to do so. The second great objection to the stub-switch is that the necessary gap between the ends of the moving rails and the stub rails cause a severe jar to the rolling stock. Into this gap (generally 2 inches wide), every wheel must drop, thereby battering the rails, jarring the machinery and running gear, and causing considerable discomfort to passengers.

Those who have had charge of large yards know how often these old styled switches cause derailment and that the least damage done is the bending of a set of switch rods, to replace which it is necessary for the trackmen to leave their work and replace them with much loss of time. The loss of track material, labor, rolling stock and the delays to traffic would soon repay the cost of safety switches. If in yards

where accidents at switches are usually not serious it is an economy to use a safety switch, how much more is it necessary to have them on the main line, when, on account of high speed, if an accident occurs, the result would be many times more expensive. With this view the State Railroad Commissions are, as a rule, enforcing use of safety switches on the main line.

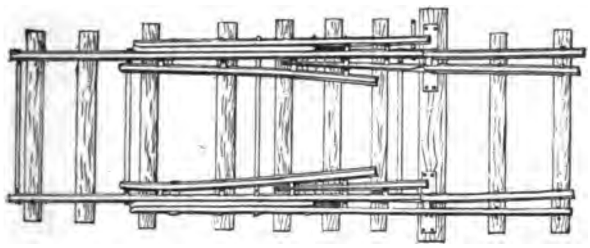


FIG. 80.—COOKE'S SWITCH.

One of the earliest forms of safety switches was the Tyler (patented 1846), in which castings were substituted in place of moving rails, of such shape as to catch wheels running off another switch and to replace them on the main track. The Tyler switch is now practically antiquated although the same principle in better form exists in Cooke's patented switch (Fig. 80), where castings are replaced by rails bolted to the moving rails. When this switch is used normally it is precisely the same as the stub, but when it is misplaced the wheels on one side run on their flanges over the filler pieces and are then drawn over the rail-head by pressure of the guard rail against the flanges of their mates, so that they drop in place. An inspection of the diagram will show how this is accomplished. While the safety device is effective, the switch, in other respects is open to the same objections as the stub.

In order to afford an unbroken bearing, the "split" or "point" switch is devised to which at the same time there is usually added some contrivance to allow the switch to be automatically thrown, in case it is misplaced, and so prevent derailment. It thus becomes a "safety" switch. These safety switches are subdivided according as the main track and turnout each have one rail continuous, or as both the main track rails are unbroken, and the wheel flanges are carried over them to the turnout.

The general principle of the first class is shown in Fig. 81, where the rail in the main track opposite the frog is continuous, while the other one is bent so as to pass unbroken to the side track, while the continuity is secured by a rail planed to a thin edge, lying close to the bent rail. By a similar planed rail the transfer is made from the main track to the siding. These planed rails are called "points," after the English term. When these points are controlled by the ordinary rigid switch-stand their sole advantage is the removal of the jar, but by introducing a spring or other device so that in case they are set against a train trailing through the switch, the wheels will push the points to one side and continue on as if everything were all right in the first place. It is, therefore, in the arrangement of this spring that the principal differences in the various safety switches lie, for with few exceptions the only special details about the points themselves are in the degree of the excellence of the manufacture or ingenuity of the methods of connecting the tie bars.

The chief difference is the varied practice of manufacturers in planing the points according to one of the modes in Fig. 82. In *A* the inside of the head is not planed parallel to the web, but at an angle so that the planing on the outside entirely cuts away the head at the toe, and the point fits under the head of the main or "stock-rail." In method *B* the inside of the head is planed away flush with the web, and the outside of the head is removed to produce the shape shown.

The sections of both styles taken about 2 feet back from the point, show clearly the principles and how the head is formed. It is claimed by adherents of *A* that with *B* the end of the point presents a surface for wheels to strike and perhaps to mount, but this, however, with proper points is not possible and can always be easily prevented by using guard rails. On the other hand it is urged against the system *A* that the strength of the point is sacrificed both by the thinness and the bearing not being directly over the web. In all cases, as the point recedes frcm the toe, the head should gradually regain its full height, so that, the point rail resting on the flange of the main rail, the head of the former will project

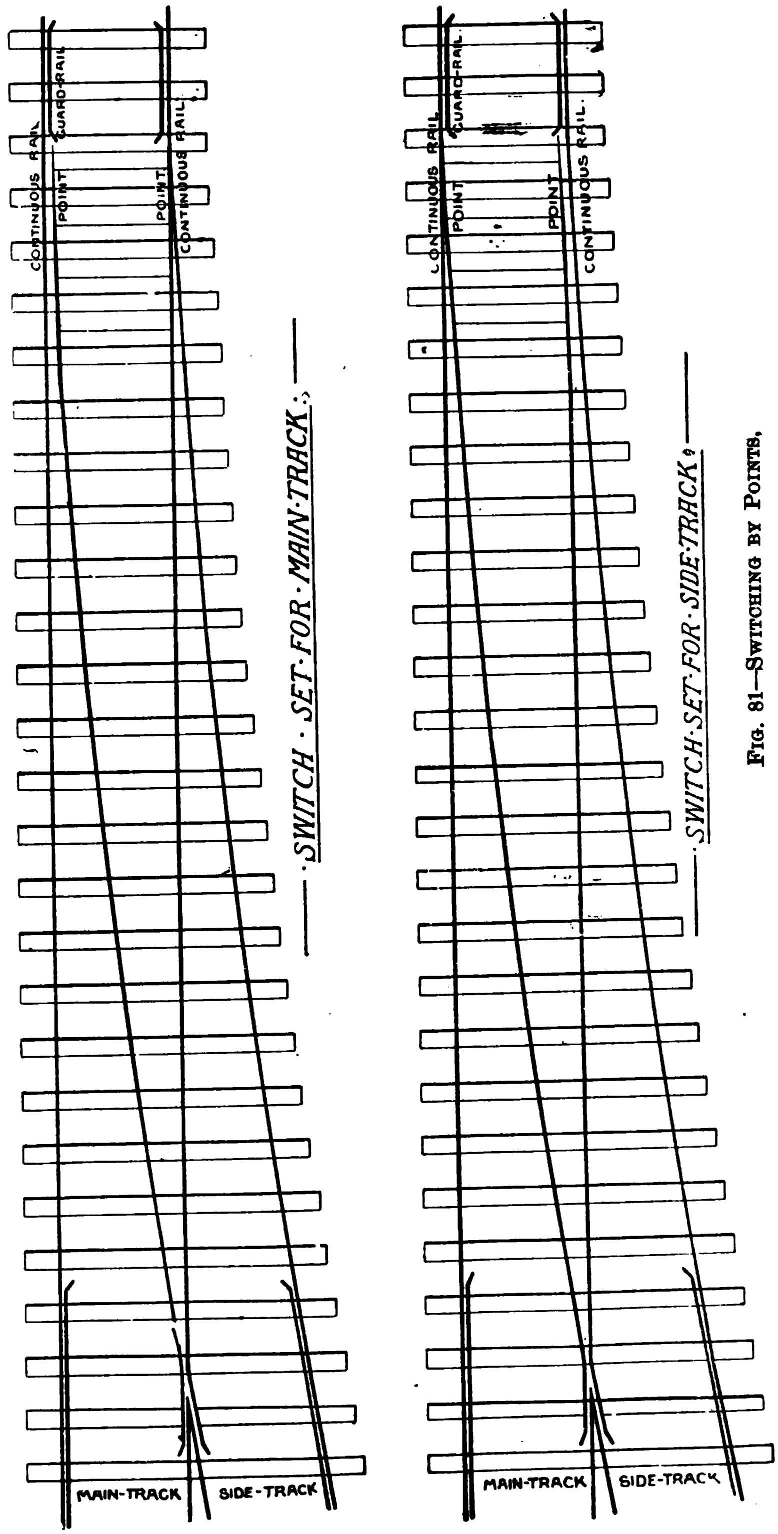


FIG. 81—SWITCHING BY POINTS.

above that of the latter, and carry the wheel. This prevents hollow ties from cutting the main rail.

There are two ways in which the spring is designed to work in case the switch is set wrong. The first, where the points are thrown by each truck in the train, the spring drawing them back each time and finally leaving them in original position, is called the "fly-back" switch; the second, where the points are held by a spring, which allows them to be thrown by the first pair of wheels and then holds them in the new position so that they cannot automatically return. The preferable method depends on the location with its special requirements. The first method, however, renders possible the danger of splitting the train should it be backed before being entirely pulled through, that is, part be on one track and part be on the other; an objection which makes the second method preferable for general use.

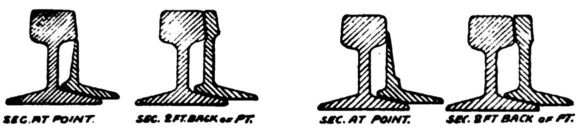


FIG. 82.—TWO METHODS OF PLANING SWITCH "POINTS."

The length of the points is entirely arbitrary, and in practice they vary from 15 to 24 feet, although generally the former figure is adopted, as being more economical of material, since a 30 ft. rail will just make two. As a rule they are straight and planed down so as to bear against the rail for about 6 to 7 feet. The throw of the point is about 3 1-2 inches, and the clear space at the heel 4 1-2 to 5 inches. They are held together by tie rods.

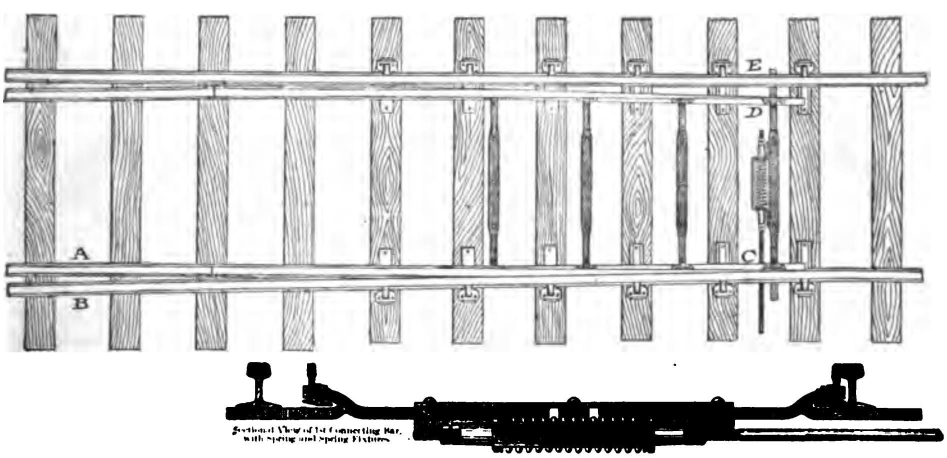


FIG. 83.—LORENZ SAFETY SWITCH.

The form of safety switch most in use is the "Lorenz," or, as different manufacturers delight in calling their own make, the "improved" Lorenz, a typical specimen being given in Fig. 83. As will be seen on inspection, a stout spiral spring is attached to the connecting bar nearest the toe, and acting through this spring is a rod passing to the switch-stand, forming the connecting link between it and the points. In order to provide easy adjustment so as to bring points close up to the rails, nuts are placed on the connecting bar at each end of the spring, to be set up as desired and so shorten or lengthen the bars..

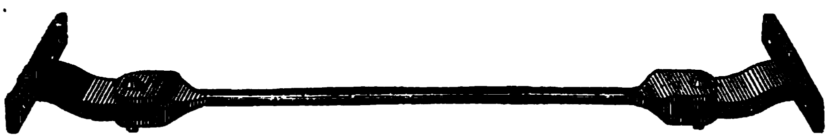
Other styles of tie bars are shown in Fig. 84, where various steps in improvement can be noticed; the last of the series is the improved bar of the Penna. Steel Co.; the fourth is the pattern in most general use.

The stand may be of any pattern, but generally is the "ground-lever" on account of its cheapness, and fig. 66 showed an admirable arrangement. The spring of a Lorenz switch, while having sufficient rigidity to move the points without compressing,

EARLY FORM OF STIFF BAR BOLTED TO RAIL FLANGE.

STIFF CONNECTING BAR BOLTED TO RAIL WEB.

FLEXIBLE CONNECTING BAR, PINNED TO LUGS RIVETED TO RAIL FLANGE.



IMPROVED FLEXIBLE BAR WITH ARMS BOLTED TO RAIL WEB.

PENNA. STEEL CO.'S PATENT CONNECTING BAR,

FIG. 84.—CONNECTING BARS.

will yield to a greater force, such as a wheel flange entering between the rails *A B*. The points being rigidly connected with each other, the point *C* is forced outwards to permit the passage of the flange between it and the rail *B*, while the point *D* at the same time is brought into contact with the rail *E*, so that the wheel tread runs off the point on to the main rail. This can be more easily understood by referring to Fig. 81. Now, this operation has to be performed by each truck of a train trailing through a misplaced Lorenz switch, therefore the Lorenz is a type of the previously described first method of operating the spring, or a "fly-back." Besides the general objection (before mentioned) of the liability of splitting a train by backing it too soon, there are two other defects to be urged against the Lorenz. First, the spring, the important detail, is in the center of the track, and although it is set below the tops of the ties, it is liable to be injured or destroyed by a derailed truck being dragged over it. Second, the switch can be locked at "safety," while being really at "danger," because if ice forms on the inside of the rail or point, or if some hard substance like a bolt or bit of gravel, gets between them, the point is prevented from coming snug up against the

rail as it should, and with the leverage of the switch-stand a man with a little exertion can fully throw it, gaining the amount taken up by the obstruction by compressing the spring. Thus, while he thinks everything is right, there may be a gap of one inch which will split and wreck the next train facing it.

Sometimes, instead of a spiral between the points there is an elliptical spring outside of the rails between them and the switch-stand, having the connecting rod in two pieces, attached to each side of it, so that, as before, the force is applied through the spring. The general principle is, however, the same as in the Lorenz.

In front of the points of all split switches there should be placed two short guard rails, 4 or 5 feet long, set the usual distance from the main rail. They are to protect the open point from loose wheels, and also to steady the truck before passing over the switch. These are given in position in Fig. 81.

Of the second method of working the safety spring, that is, to have the first pair of wheels throw the points fully and not spring them each time, there are many patterns, of which we select the following: Brahn, of the Jersey City Iron Works, makes an automatic switch stand (for in this class of switches the safety device lies in the stand), a vertical section of which is given in Fig. 85. The shaft is continuous, having the connecting rod attached to it at the bottom by an eye according to the usual manner. The handle is rigidly connected to the shaft by a hinge. We thus have simply an ordinary switch stand operating precisely like those shown in Figs. 63 and 64. In a horizontal chamber, however, lies a spiral spring pressing against a plunger and against the plunger a cam. This cam has jaws attached to it which fit the jaws fastened to the shaft. When the switch is fully thrown the projecting arm on the handle has passed by a small boss so that it can be depressed, and the long staple passes through a slot in the handle, forming a place for attaching the lock. As the handle is depressed, the standard, being loose in its bearings, falls, and the jaws engage with those on the cam, when the whole arrangement is held by the rigidity of the spring. When, however, a force is applied to the connecting rod, as, for instance, wheels pressing against the points misplaced, it is transmitted to the standard, and the stand, still locked, is automatically thrown by the compression of the spring. It will be noticed that all previous work is done with perfectly rigid connections and the spring remains idle without strain until actually called into play. The switch-stand can be obtained in two styles, either to operate as a fly-back, or else to have the points permanently thrown by the first pair of wheels. When it is worked on the principle of the Lorenz, it is superior to it, as it cannot be locked until the points are properly in place. Brahn, however, has further improved it, by adding a simple device so that the same stand by easy adjustment can be made to let the points fly back or be thrown and remain so; or fly back for one track and stay thrown for the other, so that it will always be right for one of them.

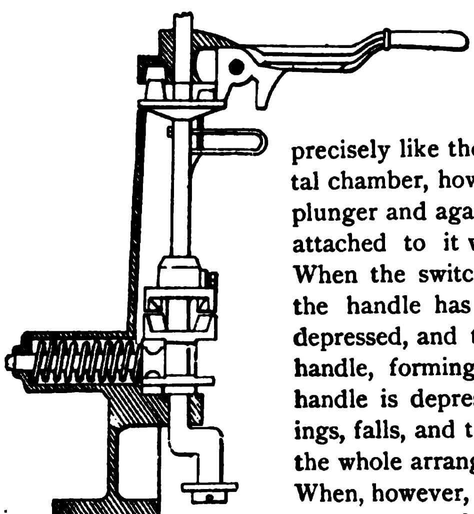


FIG. 85.—BRAHN STAND.

The Brahn stand has been described in detail as being the most ingenious, and certainly the equal, of any in the market. The whole stand is encased in a cast-iron jacket, only part of which is shown in the section. Brahn also makes a difference in

the points themselves by manufacturing the turnout point, or the one which is open or inoperative when the switch is set for the main track, longer than its mate by about 3 feet, the object being to have it act as a guard rail. Thus the wheels of a train running against a switch, as soon as they get behind the long point, are prevented against

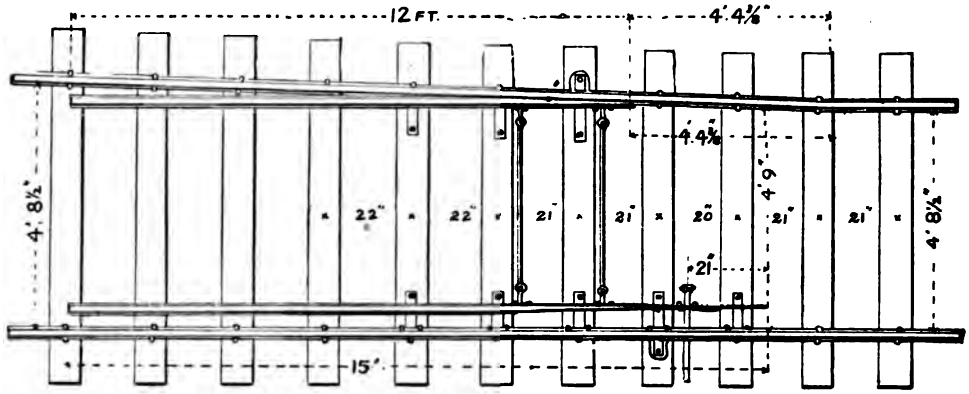


FIG. 86.—BRAHN'S SWITCH.

any possibility of mounting the other point as they run over it, even should any of them be "slewed" so as to crowd that way. As a rule it is not advisable to have a switch point act as a guard rail, and in this case it does not, as it is set wide, and only called into play as a guard rail by a very crooked truck or loose wheel, (Fig. 86). The continuous rail of the side track should be curved just as if both points were of the full length, and the gauge of the track just in front of the points should be widened 1-2 inch. This, however, it is well to do with all split switches, and the connecting bars should be of such length as to demand it.

Another excellent form of automatic stand which causes the points to be fully thrown is the Snow Stand, of which Fig. 87 is an elevation and vertical section. This stand (as they all should) gives rigid connection between the hand lever and the points when being operated by hand. When working automatically the spring is compressed and the jaws fly past each other. The handle folds down to lock. This stand takes two head-blocks to support it.

For use in yards where low stands are required there are several designs. Brahn makes one like his big stand, which makes the points fly back, and Fig. 88 shows a simple pattern manufactured by the Penna. Steel Co. which works on the other method of being

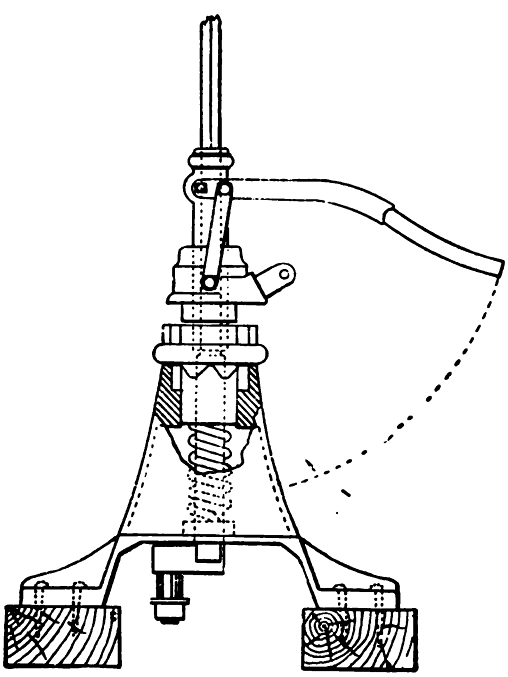
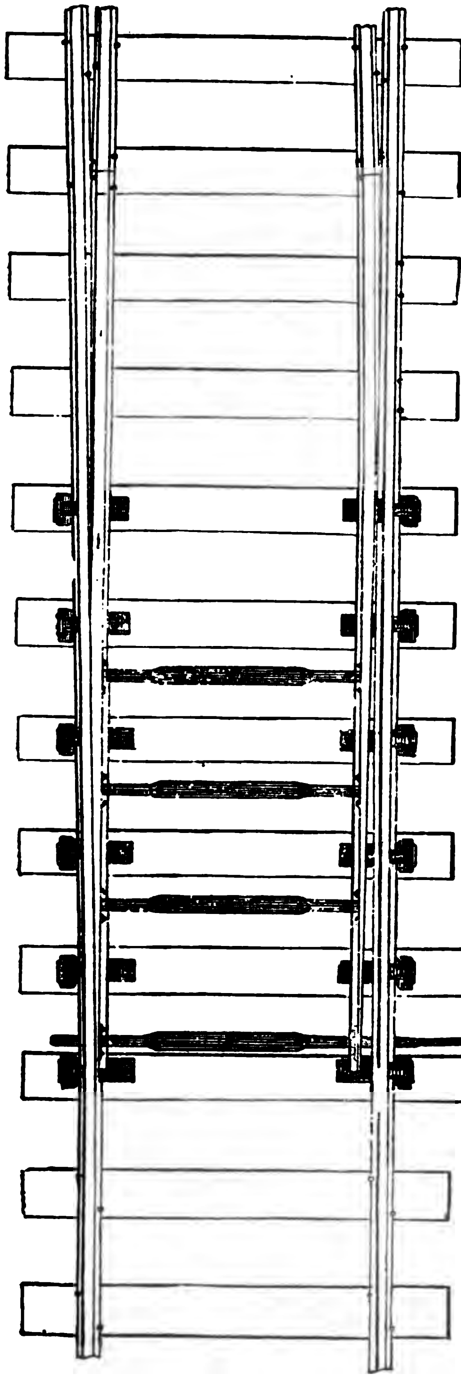


FIG. 87.—SNOW STAND.

fully thrown by the first pair of wheels. It will be seen that there is no spring, the automatic throwing being accomplished by the weight flopping over, which weight also acts as the hand lever. The intermediate mechanism consists of a rack and pinion; therefore, with no spring to compress, the points must be home before the weight drops down on the block. In case the switch is locked as indicated, and a train attempts to pull through it when set wrong, the result would be the breaking of the weakest part, which is the lock latch and the weight would be free to go over. A standard with target and lamp can be added if desired.

Beside the double pointed, there is quite a numerous class of single pointed switches usually adopted in yards, with low num-



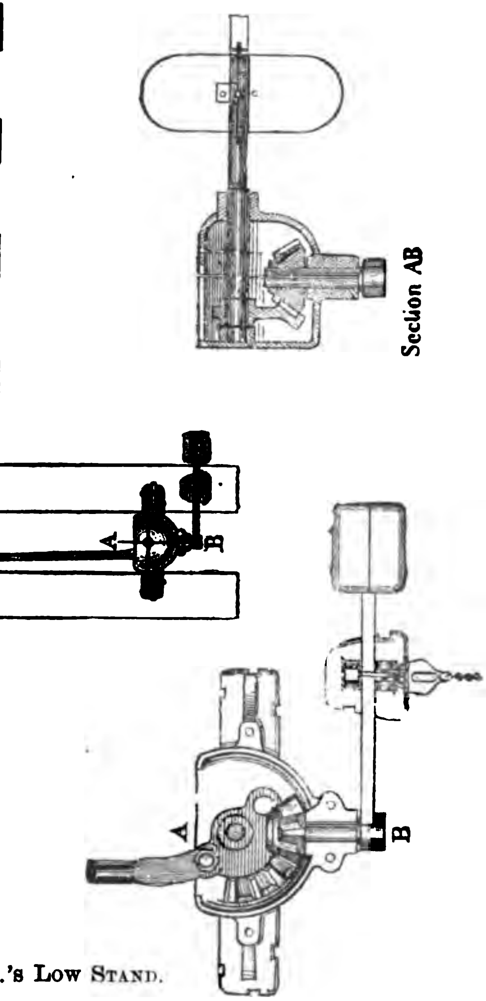


FIG. 88.—PENNA. STEEL CO.'S LOW STAND.

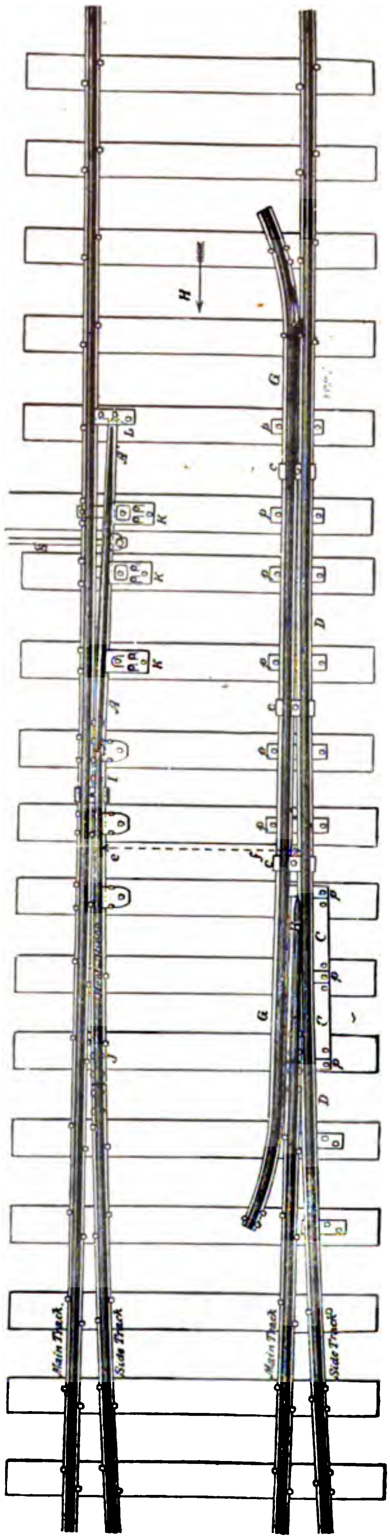


Fig. 89.—Tracy Switch.

bered frogs, to save room. As probably the best of these, we select the Tracy, although it was designed for a more ambitious field than yard work. Fig. 89 shows a plan of the switch set for the main track. It will be noticed that there is a short, movable point *A A′* connected with the switch stand by the rod *g*. Where, with double pointed switches, there should be another point, there is now a stationary rail *B*, called a frog point. *G G* is a guard rail spiked only at the ends and fastened by the three yokes *c c c* to the spring rail. *D* is also spiked only at the ends. When the switch is set right for

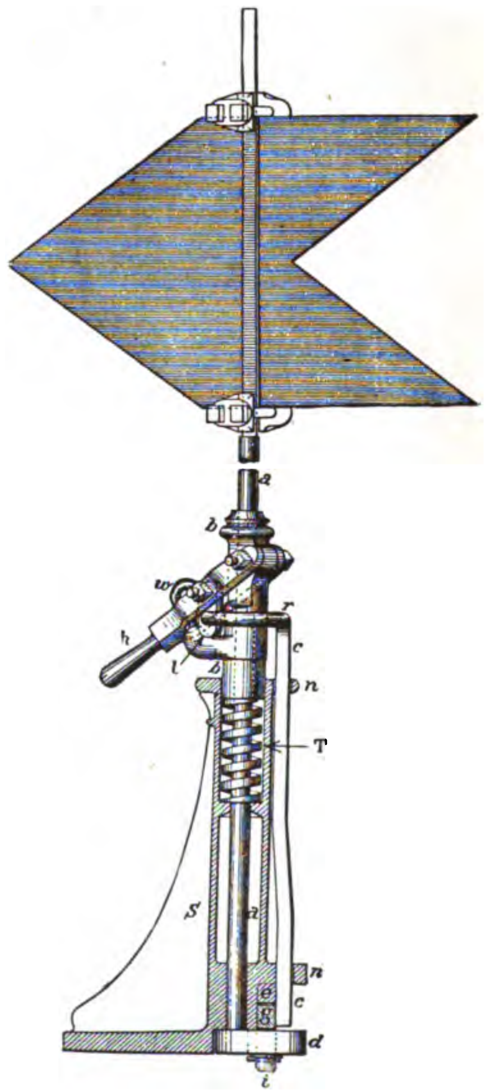


Fig. 90.—Tracy Switch.

a train pulling into or out of the siding, each pair of wheels getting a purchase on either the heel piece or the moving rail, forces outward the spring and guard rails together so as to give passage room for the flanges between *D* and the frog point *B*. When the switch is misplaced, the point *A* is set right by the first pair of wheels. It will be seen that where the heel piece and moving rail join at *I*, they are set quite close to the main rail. They thus act as a guard rail to keep wheels on the main track from striking the blunt point of *B*. Other single pointed switches usually have a regular frog arrangement instead of a spring rail.

Fig. 90 gives view of the Tracy stand with one-half of the cast-iron casing removed. It belongs to the same general class as the Snow, that is to say, it is a positive throw for both tracks. As a class, switches with single points are inferior to those with double points, the special objection to the Tracy being that it depends on the constant elasticity of two rails and relies for security on the three yokes *c c c*.

All point switches have one rail in each track continuous. There is however one switch, the Wharton, which leaves both main track rails unbroken, the wheel flanges being lifted over. Fig. 91 shows the full working plans. *A* is a grooved rail, the cross-section of which is given, connected with the elevated rail *B* by five clamps or connecting rods—*T*, *U*, *V*, *W*, *X*, and in turn the elevated rail is in connection with the crank shaft *D*, through the draw rods *E*. Thus, by turning over the weighted lever the grooved and elevated rails are moved like the points in split switches. B, the elevated or "camel back" rail, is one of the ordinary pattern curved vertically and resting on a graduated series of iron blocks, so that while its point is level with the top of the main rail it gradually gets higher, and about 8 feet back from the point is 1 1-2 inches above main rail. When the switch is being operated the outside of the wheel treads bear upon the elevated rail and the whole wheel is gradually raised by it, while at the same time the other wheels have entered the groove and are resting on the outside rim of the channel, and when the proper clearance is gained the inside wheel is carried over the top of the main rail and thus the transfer is made.

Its automatic working is also simple. When it is set wrong for the main track, the movable guard rail *C* is brought in close contact with the main rail, for one end of this little rail is firmly held by the chair *L* and the other is free to be controlled by the crank shaft through the means of draw rod *F*. When thus set wrong the first pair of wheels entering between the guard rail and the main rail throws the former out, which motion is immediately transmitted to the crank shaft; the weighted lever is thrown over and the switch is moved as if by hand. If left wrong for the side track (as shown in the figure) the switch is not moved, but the wheels, when they reach the end of the elevated and grooved rails, drop on their flanges upon the two safety castings, *N* and *O*, cross sections of which taken at *X'X'* are given in Fig. 92. The rib of casting *O* serves as a guard rail, while at the same time the opposite wheels run over the top of *N* and the adjoining rail and drop into place.

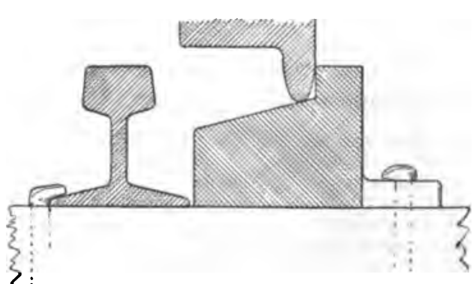


FIG. 92a.—CROSS-SECTION. WHARTON SAFETY CASTINGS.

The great advantages of the Wharton switch are the unbroken main rails and the fact that the apparatus when not in use is entirely out of the way and not subject to wear. Against it is urged its

cumbersomeness and the space required. These objections probably prevent its general use in yards, where ground has to be economized, or at points where it is likely to be subject to fast running trains. But for way stations and outside switches the Wharton is an admirable device.

In treating of the subject of frogs and switches it is impossible to show every patented device; the aim here has been to make clear the general principles of operation and to present types of the different classes of devices showing as far as practicable their prominent features. The questions of "interlocking" by the different systems, with their beautiful and elaborate details belong to a different field.

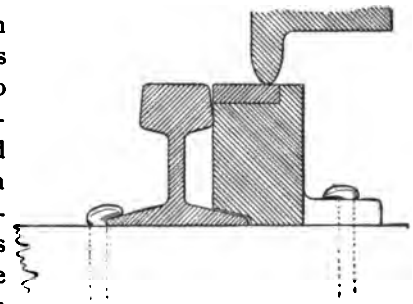


FIG. 92*b*.

Ordinarily when a "thoroughfare" track in yards is to be run across a set of parallel tracks and to be connected with each, it is necessary to put in a crossover from track to track, an arrangement that takes up a great deal of space and renders obligatory the throwing of every switch when a train is to be run over the thoroughfare. In order to obviate both these difficulties there is now being introduced the English "double slip" device shown in outline in Fig. 93. The crossing track or thoroughfare begins as an ordinary turnout and is continued straight over the parallel lines by means of ordinary crossing frogs. In order to connect it with each one of these lines so that a train can pull from one parallel to another or can enter the thoroughfare from any one of them, there are laid down at each crossing two turnouts or slips. Each of these slips is double, that is, has points at both ends with tie-rods and switch-stand exactly similar

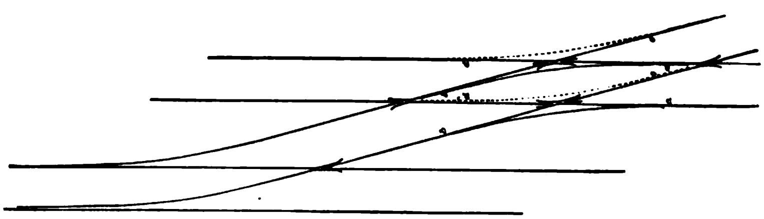


FIG. 93.—DOUBLE SLIP SWITCH

to an ordinary switch. An inspection of the diagram will explain how the slips are used, and to distinguish this clearly the rails of the thoroughfare and one of the system of parallel tracks are drawn in heavy lines, while the rails of one slip are indicated by light and those of the other slip by broken lines, while the letters *aa*, *bb*,

---

The following table names the various parts of the Wharton Switch, reference being made to the cut on page 67:

A, Groove Rail, 100 lbs. per yard.
B, Elevating Rail.
C, Movable Guard Rail.
D, Crank Shaft.
E, Draw Rods.
F, Guard Rail Draw Rod.
G, Groove Rail Clip, Bolt and Nut.
H, Set of 7-8 inch Bolts for Elevated Rail.
I, Set of 7-8 inch Bolts for Groove Rail.
J, Elevating Rail Chair.
K, Groove Rail Chair.
L, Movable Guard Rail Chair.
M, Crank Shaft Stands.
N, Short Safety Casting, Steel-plated.
O, Long Safety Casting.
P, Stand and Revolving Target.
Q, Target Lantern.
R, *S*, Blocks.
T, *U*, *V*, *W*, *X*, Clamp Rods.

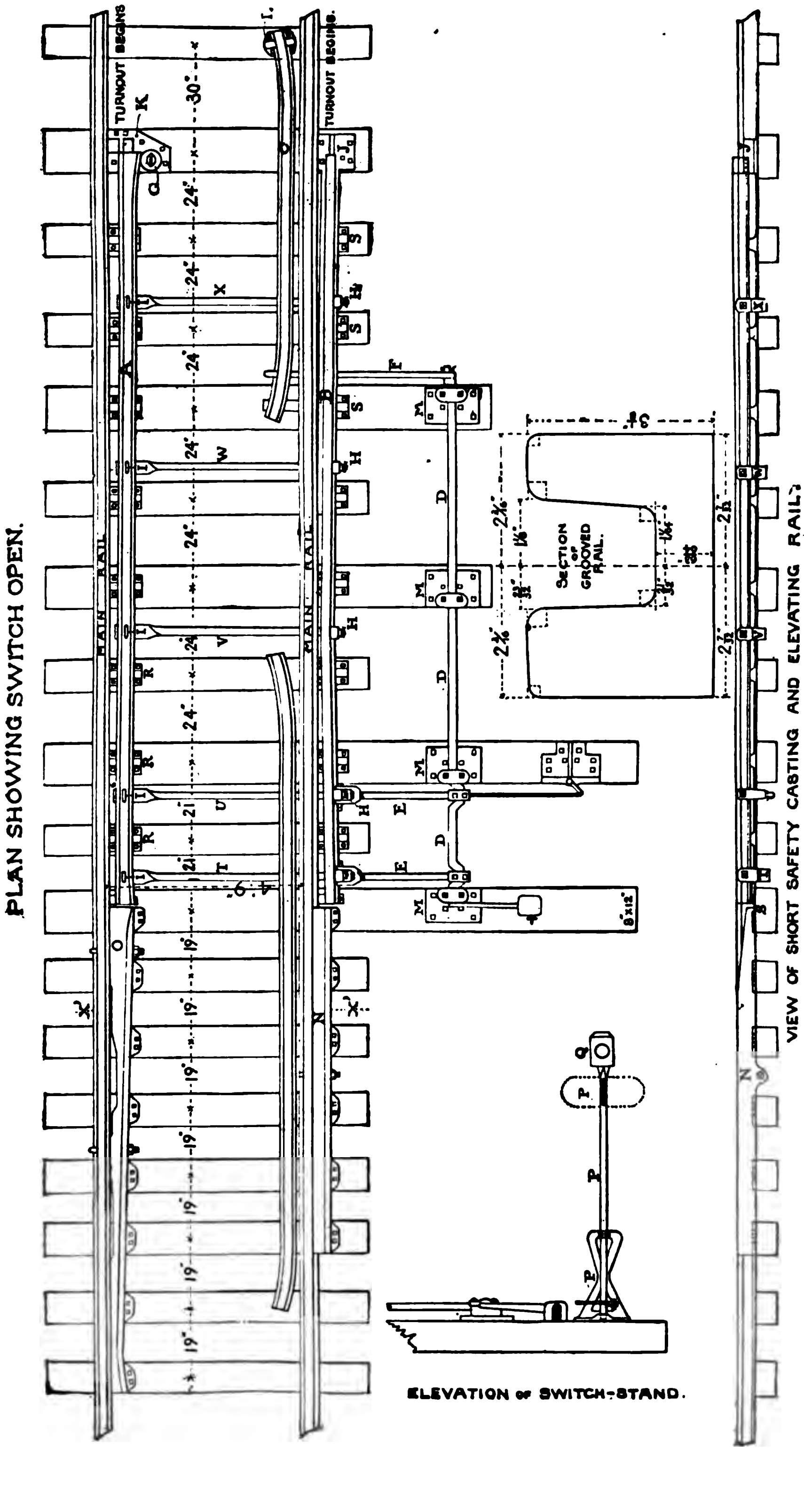


FIG. 91.—WHARTON SWITCH.

cc, *dd* show the corresponding points by pairs. This combination of crossing frogs and slips instead of a series of crossovers is most admirable for great economy of room and convenience in operation, while it is no trouble to maintain them above attention necessary to be given to frogs and switches.

Putting in a turnout is commonly a stumbling block to trackmen, because they seem to have a desire to invest it with mysterious properties not belonging to any other curve, and they seem to lose sight of the direct problem in hand. It is really very simple. In general practice the exact position of the turnout is not a positive fixture, so that we can move up and down the track for a few feet in order to select the most convenient location.

If this can be done, decide on a joint with which to connect either the heel or the toe of the frog, and so save one cutting of a rail. From this joint lay off the distance of the frog point from the heel or the toe, according to which part of the frog it has been decided to connect the joint in question, and mark that spot on the rail with chalk.

This denotes the location of the frog point and forms our basis for measurements. Take from table No. 1 the "lead" distance, add to it the amount cut off the frog point by its bluntness and lay off the distance thus obtained from the chalk mark and make another, which will give the location of the head-block. Beginning there and working towards the frog point, make marks on the rail every 22 1-2 inches as many as there are ties in the set corresponding to the frog number. Then take out the cross-ties and put in the head-block, and under each one of the other chalk marks put in a switch tie, in regular order, lining the ends carefully with the main track rail on the side opposite from which the turnout is to be, while the other ends, provided the ties are properly sawed, will line up on the turnout side according to the required curve.

These ties should be well tamped their whole length, particular attention being given to the frog ties. If the frog is of the bolted or keyed pattern, with the rails bearing directly on the wood, the ties underneath the frog should be tamped about 3-8 inch high in order to allow for settling. If however a plate frog is used, these ties should be tamped at the ends first and allowed to sag a little in the middle so as not to necessitate the scoring of the timbers for the plate. Everything is now ready for the rails. Cut one rail long enough so that, together with the frog, it will just fit in the place of the one decided on to be taken out, and next measure back from the center of the head-block, 30 feet for the moving rails and cut other rails to close the gaps between them and the nearest joints.

Do the same with respect to the next joints in front of the head-block, which gives all that is required for the main track; avoid, however, a joint opposite the frog point and short pieces running into the head-chair. Should it happen that a joint is close to the head-block it is better, instead of using a very long and a very short rail, to have two of medium length. Now put in the frog together with the guard rail for the main track and make the necessary changes for the moving rails, slipping the head-chairs and switch rods in place at the same time. The next step is the lead rails.

It was previously stated that these rails should conform to a regular arc of a circle. A foreman with an accurate eye can run in the curve without aid, but it is better to lay it out. This is done with the help of table No. 6 which gives for the different curves a series of ordinates or the distances from main rail to lead rail measured

between the "gauge lines" at every ten feet. If one size of rail is in use, this table can be made more convenient by adding to each ordinate as given, the width of the rail head less the width of the base, by which we get the distances between the rail flanges instead of the gauge lines. To use this table thus corrected, at every

Table No. 6.—Ordinates.

Frog Number.	DISTANCE, IN FEET, FROM HEAD BLOCK.															
	10 ft.		20 ft.		30 ft.		40 ft.		50 ft.		60 ft.		70 ft.		80 ft.	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
5	3	6	2	3¼	0	7¼										
5½	3	7	2	6¼	1	1½										
6	3	7¾	2	8½	1	5¾										
6½	3	8½	2	10½	1	9½	0	5½								
7	3	9¼	3	0¾	2	0½	0	10¾								
7½	3	9¾	3	1½	2	3	1	2½								
8	3	10	3	2¾	2	5¼	1	5¾	0	4¾						
8½	3	10½	3	3½	2	7	1	8¾	0	8½						
9	3	10¾	3	4½	2	8½	1	11	1	0						
9½	3	11	3	5¼	2	10	2	1¾	1	3	0	3½				
10	3	11¼	3	5¾	2	11	2	3	1	5¾	0	7¼				
10½	3	11½	3	6½	3	0¼	2	4¾	1	8	0	10¼				
11	3	11¾	3	7	3	1	2	6¼	1	10¾	1	1	0	3		
11½	4	0	3	7½	3	2	2	7½	2	0	1	3½	0	6¾		
12	4	0	3	7¾	3	2½	2	8½	2	1½	1	5¾	0	9		
12½	4	0¼	3	8¼	3	3¼	2	9½	2	3	1	7¾	0	11½	0	2½
13	4	0½	3	8½	3	4	2	10½	2	4¼	1	9½	1	1¾	0	5½

ten feet from the head-block lay off the ordinates belonging to the frog perpendicularly to the main rail opposite the frog and mark the distances with chalk on the nearest tie. Having connected the lead rails with the frog and head-chair throw the "string" until the inside edge of the flange exactly cuts the chalk mark on the ties. Spike the rail at these points and line it between them by sight. We thus have the curve correctly laid out and far more rapidly than could be done by eye.

If the ordinates are used as given in the table and not corrected to be between the flanges, it is necessary to hold a rule at each ten feet and draw in the lead rail until there is the requisite distance between the inside of its head and that of the main rail. It is evident that the flange method is easier. Fig. 70, which gave the plan of a No. 8 turnout, showed also the ordinates. The inside lead rail is laid by gauge from the outside rail.

Inasmuch as for commonly used frog numbers the curve is sharp, it is, therefore, well to widen the gauge slightly on the turnout about 1-2 inch opposite the frog point, and gradually run it out to nothing at the head-block; the allowances can be easily made when gauging.

After setting up the switch-stand and putting in the other guard rail (remembering to secure the guard rails with knee braces), the turnout is ready for use. The operation is perfectly simple, there is nothing mysterious in it, nor any trick, as many try to believe. If it is a "point" or a "Wharton" in place of a stub switch, the method of procedure is the same, except that the "total lead, heel to frog point" instead of "head-block to frog point" must be taken from table No. 1; and the switch itself is put in according to its own individual requirements. This distance in table No. 1 was calculated with a moving rail which when thrown gives a continuous curve, and therefore to be perfectly correct the switch points should be curved, not straight. Although this is sometimes done it is not usual on account of expense and so points are made straight, 15 feet long, and with a uniform throat distance at heel without regard to

angle of frog with which they are to be used. If frog is No. 8 or less the error between frog distance depending on curved or straight moving rail is not sufficient to appear practically. With frogs of higher number than No. 8 the distance given in table No. 1 should be slightly reduced, otherwise a good line will not result. For such frogs, however, the points should be made curved, or longer than 15 feet in order to conform better with the longer radius.

With a frog in a straight track some trackmen spike the gauge wide, others contract it, and the claim of both sides is that the frog rides better for it. The proper plan is to proceed exactly as if there were no frog there, for a frog should be considered a part of the rail, and the track spiked opposite the frog point exactly as it is on each side of it, so as to obtain a true line on both rails. If it is a turnout from a curve, leave the gauge opposite the frog on the curve the same as the rest of it, and so remember that while it is advised above to widen the gauge on the turnout side, that is not necessary because it is a frog, but because it is a sharp curve. It is well to bear these points in mind, as they have proved of much difficulty to trackmen who, as was stated before, seem to think that there is something abnormal in regard to frogs.

Sometimes a frog is continually the cause of derailments, and the foreman will keep on reporting it as all right. An intelligent examination will generally show the cause of the trouble to be one of three things. First, the guard rail loose or set too wide. Second, the gauge contracted. Third, the frog badly out of line. As to the cost of putting in a turnout complete, taking a No. 8 frog as an example, it will occupy a gang of 8 men and a foreman one day. This includes all the work of taking out the old cross-ties and putting in a set of switch-ties according to the table, together with the placing of the frog, rails, etc. As to the extra labor for patent switches, 4 men and a foreman can put in a Wharton, including the ties, in half a day, and that pattern takes more time than any of the other forms.

CHAPTER V.

FENCES — CATTLE GUARDS — ROAD CROSSINGS — SIGNS — BRIDGE-TELLTALE BUMPING-BLOCKS—MAIL CRANE—TOOL HOUSE— WATCHMAN'S CABIN—SHANTY.

FENCES.

Fences form a very important part of maintenance of way. The obligations of the company in this matter are subject to State law; and the same authority, supplemented by county or township ordinances, regulates the kind of fence, material and height, which regulations should be carefully studied for each locality.

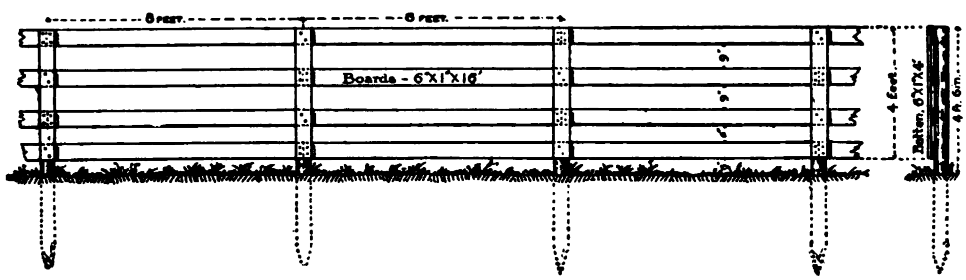


FIG. 94.—BOARD FENCE.

The fences in most general use on railroads are the "post and board" or some variety of wire. The old fashioned "post and rail" is too expensive and the English hedge takes up too much space. Therefore, only the first two are recognized as standards, and will be so treated here.

The "post and board" fence, Fig. 94, consists of wooden posts 8 feet apart set in the ground so as to accommodate the market length of 16 foot lumber. The posts should be of timber which resists decay, cedar and chestnut preferably, and their dimensions should be 8 feet long with a diameter of not less than 4 1-2 inches at the small end. Split posts are not as durable as the full round. The posts should be sunk in the ground not less than 3 feet, and the most stable manner is tc "set" them, but for economy they are generally pointed and driven, unless the ground is too hard. Probably the best practice lies between the two, by digging the hole 1 1-2 feet and then driving the remainder, which permits of a solid tamping or ramming of the earth around the post. Before using, the posts should be stripped of the bark, as this latter when dry, gives fire an easier chance to destroy them. The boards, which should be nailed to the posts at regular spacing, are usually of that lumber most plentiful in the district and which can be obtained cheapest, such as pine, hemlock, etc. The size is entirely arbitrary varying in width from 6 to 12 inches, though the thickness is almost always 1 inch.

It is common practice to have the four boards of different widths, narrowing toward the top, in order to have a close fence at the bottom against small animals, a practice not advisable since it renders necessary three or four different sizes of boards with consequent trouble and expense of sorting. The better plan is to use one size, and to space the boards so as to gain the same effect, as shown in the figure. It is well for strength to lay the boards on so as to have alternate rows break joints, although usually this is not done in order that the fence may be taken down by panels if so desired; but in all cases the boards should be placed on the field side of the post so that the pressure, which always comes from that side may be against the post, and not on the nails, a detail which is frequently neglected.

On the outside of the boards a batten should be nailed to secure the joints and hold all the boards fast; it can be made out of 6 inch stuff 4 feet long, so that one 16 foot board will make four.

The nails used should be 10d, and for the battens 12d. The posts should be sawed off square with the top of the upper board, otherwise the ends projecting irregularly present a most unsightly appearance. Fig. 94 shows the dimensions for a fence 4 feet 6 inches high, which, with that of 4 feet is usually considered as legal.

The wire fence is of recent origin and may still be considered as in its infancy, but there is so strong a prejudice against it, that many of the States have been obliged to take action on its legality. In some it is illegal, in some legal, while in others it is only lawful for highways and not for a division fence without the consent of both parties.

There are many widely differing styles of wire and no recognized standard for a fence of this character. Some parties space the posts the same distance apart as a board fence, others 10, 12, 16, 20, 24 or even 30 feet apart according to their personal ideas; probably the most common practice is to set the posts 16 feet apart, which should certainly be the maximum limit, for if greater than this the fence becomes weak. In favor of 16 feet there is the strong argument that if at any time the State declares a wire fence to be unlawful, or for other cause it is desired to return to a wooden fence, by simply setting the alternate posts, it becomes ready for the boards. In order to stiffen the wires, when the posts are set 16 or more feet apart, there are several patent devices of rods interlacing the wires midway between the posts, or there may be used, to gain the same effect, a strip of wood about 1 inch × 2 1-2 inches held to each wire by a staple. Better, however, than 16 feet is 12 feet, like Fig. 95, at which distance the fence is perfectly stiff and strong.

In putting on the wire the strand is attached to the first post, and then pulled taut, when it is secured to all the other posts by staples. If the ground is not sufficiently strong to hold the posts stiff to resist the strain of stretching the wire when putting it up, at about every twentieth panel there should be a straining post braced like the center post in the diagram, and all corner posts and the original starting post should be held in this manner.

Wire fence is made with 3, 4 or 5 strands according to the kind of cattle against which it is used. But 4 strands should be the minimum number, and 5 is preferred, especially if sheep and hogs are to be enclosed.

One of the objections against wire fence is that cattle cannot see it before they run hard against it. To meet this objection a strip of wood, about 2 × 4 inches, is

nailed on top of the posts. Fig. 95 shows two styles of wire fence, one with a wooden strip and four strands of wire, the other with five strands. The existing prejudices against wire fence are based on the injury the barbs do the cattle, its indistinctness permitting animals to run hard against it and sometimes to get entangled so as to re-

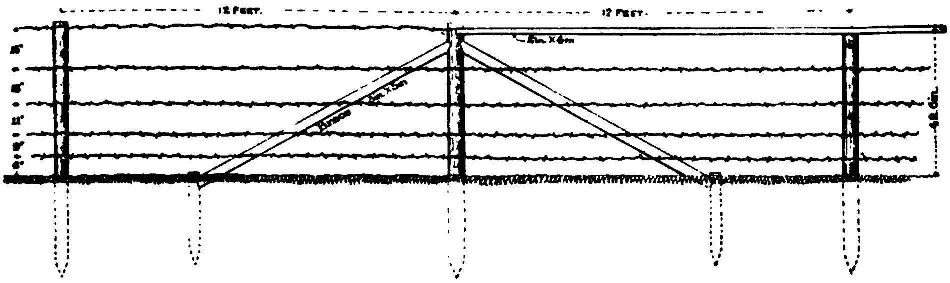


FIG. 95.—WIRE FENCE.

ceive severe injury. On the other hand it makes a fence less expensive in cost, more permanent and durable, one which fire and wind will not hurt, which will not cause snowdrifts in winter and of which the expense of repairs is small. In selecting a wire, judgment should be exercised to choose one which is strong and elastic, so as not to suffer from contraction and expansion, one which is distinctly visible, and whose barbs cannot inflict injury. Although like many other innovations it meets with partial disapproval from the outset, yet undoubtedly a metal fence of some description is the fence of the future.

In addition to ordinary wire fence as above described there are several patent forms where the whole fencing is made in rolls and needs only to be attached to the posts, which are sometimes made of iron. These devices are still in an experimental stage.

The subjoined table gives bills of material for one mile of post and board fence, like Fig. 94, and for the same distance of 5 strand wire fence, with posts 12 feet centers, like Fig. 95, and also the amount of labor in each case required for erection. With present prices (1886) the cost of the wood fence is greater in the proportion of 4 to 3, but by putting the posts 16 feet between centers, with 4 strands of wire, as is usually done, the cost of the metallic fence is proportionately decreased.

POST AND BOARD FENCE—ONE MILE.

660 posts; 1,320 boards, 6″ × 1″ × 16′ = 10,560 feet B. M.; 660 battens, 6″ × 1″ × 4′ = 1,320 feet B. M.; 250 lbs. nails; 65 days labor.

WIRE FENCE—ONE MILE.

440 posts; 26,400 feet wire—about 440 lbs. per strand = 2,200 lbs.: 75 lbs. staples; 27 days' labor.

Fig. 96 is a plan of a farm gate, for whether the fence is of boards or wire, it is best to make the gate of wood. The illustration needs no explanation. The cost of labor for such a gate is: carpenter, 1 2-3 hours, blacksmith (hinges and hooks), 2 hours.

CATTLE GUARDS.

At road-crossings, the State law usually requires cattle guards to prevent cattle from straying down the track. Some States leave the style of guard as a matter of selection, as for instance, the statute of the State of New York which calls for cattle

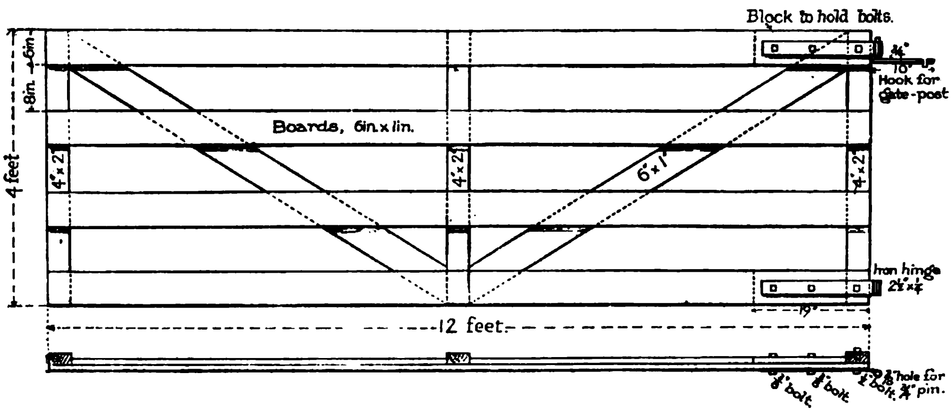


FIG. 96.—FARM GATE.

guards "good and sufficient." Where such latitude of choice exists there are several kinds to select from. A good type of the form most generally seen is Fig. 97, the

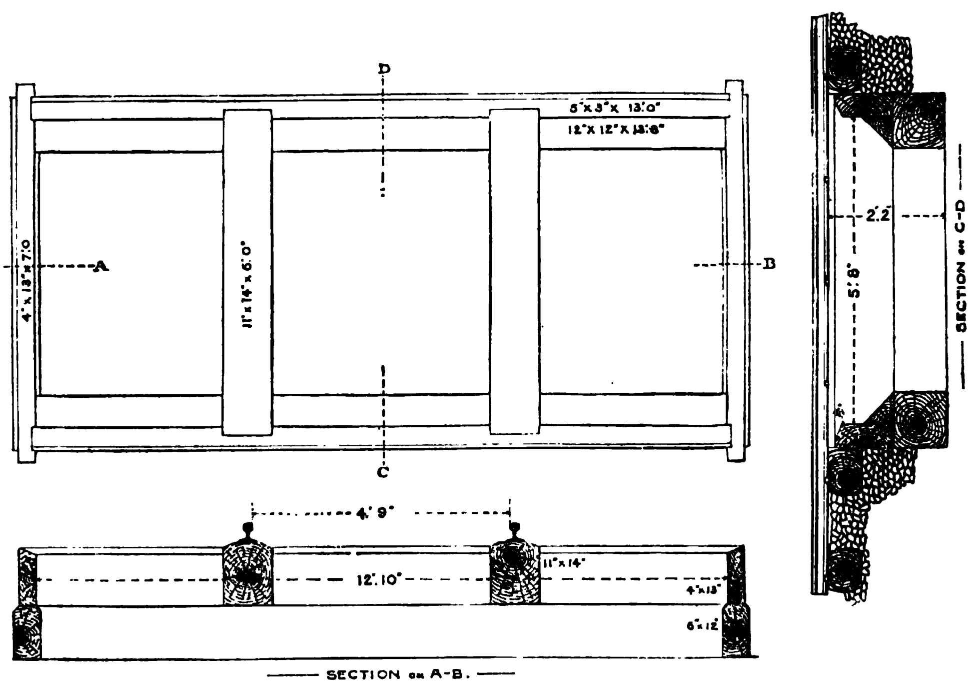


FIG. 97.—PENNA. R. R. STANDARD CATTLE GUARD.

standard of the Penna. R. R. This is an open pit walled up on all sides, the rails being carried by stringers. There are many objections against this form. In general it is bad practice to lay the rails directly on the stringer, for should a derailed truck be dragged over an open pit, there is great probability of its falling in,

resulting perhaps in a serious accident. Secondly, large cattle may get into the pit, in which position they are liable to derail a train. Thirdly, unless the ballast is good, the track on either side heaves, necessitating the bad work of blocking on stringers or the generally difficult work of blocking under them. Fourthly, they soon lose their effectiveness by being filled up unless constantly cleaned.

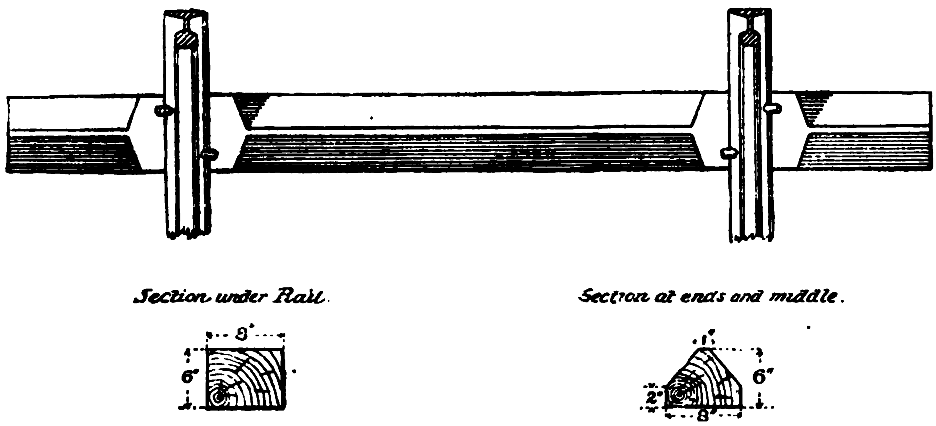


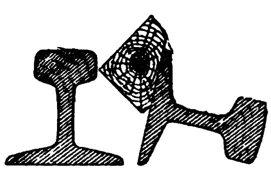
FIG. 98.—PLAN OF CROSS-TIE FOR CATTLE GUARD.

In order to avoid these difficulties, sometimes bevelled ties, Fig. 98, are laid on the stringer, the full face of the tie being left under the rail while the other parts are triangular with the apex uppermost, which meets all but the second objection and this danger is increased, for, if a large animal should attempt to walk over the ties (and they do), the almost inevitable result would be the dropping through of its legs and thus the beast would be held in a position dangerous to trains. Sometimes instead of having ties the rails are laid on stringers, and wedge-shaped pieces parallel with them are laid over the whole opening, giving what is known as the "gridiron" cattle guard. This however, possesses all the disadvantages, and none of the advantages of the bevelled tie. A cattle guard quite as effective as any other to turn stock, one that is perfectly safe and more economical than those described is the "slat" cattle guard, Fig. 99. The slats are sawed out and held together by iron rods, being separated by spacing pieces of suitable size. Each section can thus be lifted up to permit the regular track work to be performed. Between the tracks two or three ties are put in as stringers, and to them and the regular ties the slats are secured by nails. No especial arrangement of the ties is necessary, except that they should be of even surface, sawed ties thus giving the most satisfactory results. Cattle will not walk upon these edges but will jump them if the slats are not too long. In order to form continuous barriers between the cattle guards and the fence, the latter is turned and run down across the right of way along side of the road until it meets the cattle guard, whatever form this may be. The end of the fence should be sloped so as to permit its foot to be placed as close as possible to the rail. The full details of the fence are given in Fig. 99, where it is shown in connection with the slat cattle guard; should the contour of the road-bed be such as to leave a large opening under the bottom board over the ditch, the space can be stopped by a diagonal board as indicated by the dotted lines on the right hand side of the diagram. These fences and slats should be whitewashed so as to render the road crossing more distinctly visible both to enginemen and teamsters, as well as for neat effect. It is also possible that a white glaring surface tends

to turn cattle. The labor of equipping a road-crossing with four such fences, the right of way being 100 feet wide, is 5 men for 1-2 day.

ROAD-CROSSINGS.

Whenever a railroad crosses a highway or other passage for vehicles at grade, arrangements must be made for letting the wagon wheels pass easily over the rails. Usually this is done by planks spiked to the ties, which planks vary in width from 8 to 12 inches and in thickness 3, 3 1-2, or 4 inches according to the height of the rails and the requisite degree of exactness in being flush with its top. In cases of streets and very important highways the space between the rails and between the tracks should be planked solid, leaving only a gap of 2 1-2 inches along the inner side of the rail for the wheel flanges. Where much travelled over, the planks should be nailed to the ties with wrought spikes, and the ties be sawed to give an even bearing, while to carry the planking between the tracks other ties should be interlaced with the cross-ties and be spiked to the rails of both tracks. By these means the planking is securely attached to the track and cannot be affected by frost independently of it. On top of the ties and beneath the planks there should be nailed thin strips of wood or "furring" of the same thickness as the rail base so that the plank next to the rail will lie flat and not be higher than the rest. On the inside of the rail in order to protect the planking at the flange space there is usually spiked a guard rail parallel to the main rail and the planking laid up against it. Instead, however, of standing this rail upright it is better to lay it down and arrange according to Fig. 100. The disadvantage of the upright rail is the liability of horses catching their toe calks in the space under the heads which accident is prevented by the filler shown in Fig. 100, which also gives better facilities for the removal of snow and ice. At important roads and farm crossings it is unnecessary to plank entirely across between either rails or tracks. One plank each side of the rail is sufficient by filling in between them with ballast, which if possible should be stone or coarse gravel. To keep this filling in place a



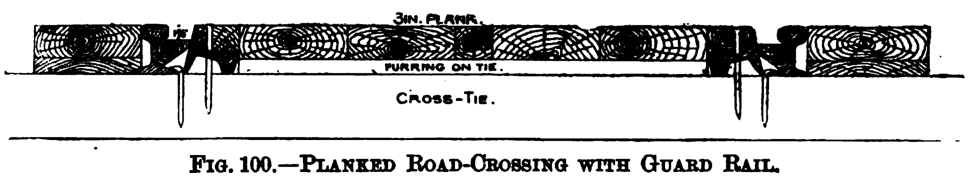


FIG. 100.—PLANKED ROAD-CROSSING WITH GUARD RAIL.

cross strip connecting the ends of the planks can be put in. The outside of this cross strip and the ends of all planks should be beveled so as not to catch low brake rods.

This arrangement is shown in Fig. 101, with two styles of approach over the ditch, one a bridge of ties and plank, the other a fill with pipe drain. The length of the crossing should be regulated according to the travel over it. Thus, it is sufficient to make an ordinary farm crossing 8 feet long, unimportant highways 12 feet, and principal thoroughfares and streets according to local requirements. The best material to use for planking is Georgia yellow pine, which is very durable, lies flat and does not twist or curl, the last named qualities being the objections to oak. In winter the planks at farm crossings and wherever else possible should be taken up to avoid the liability of their being raised by frost and striking engine pilots or snow ploughs.

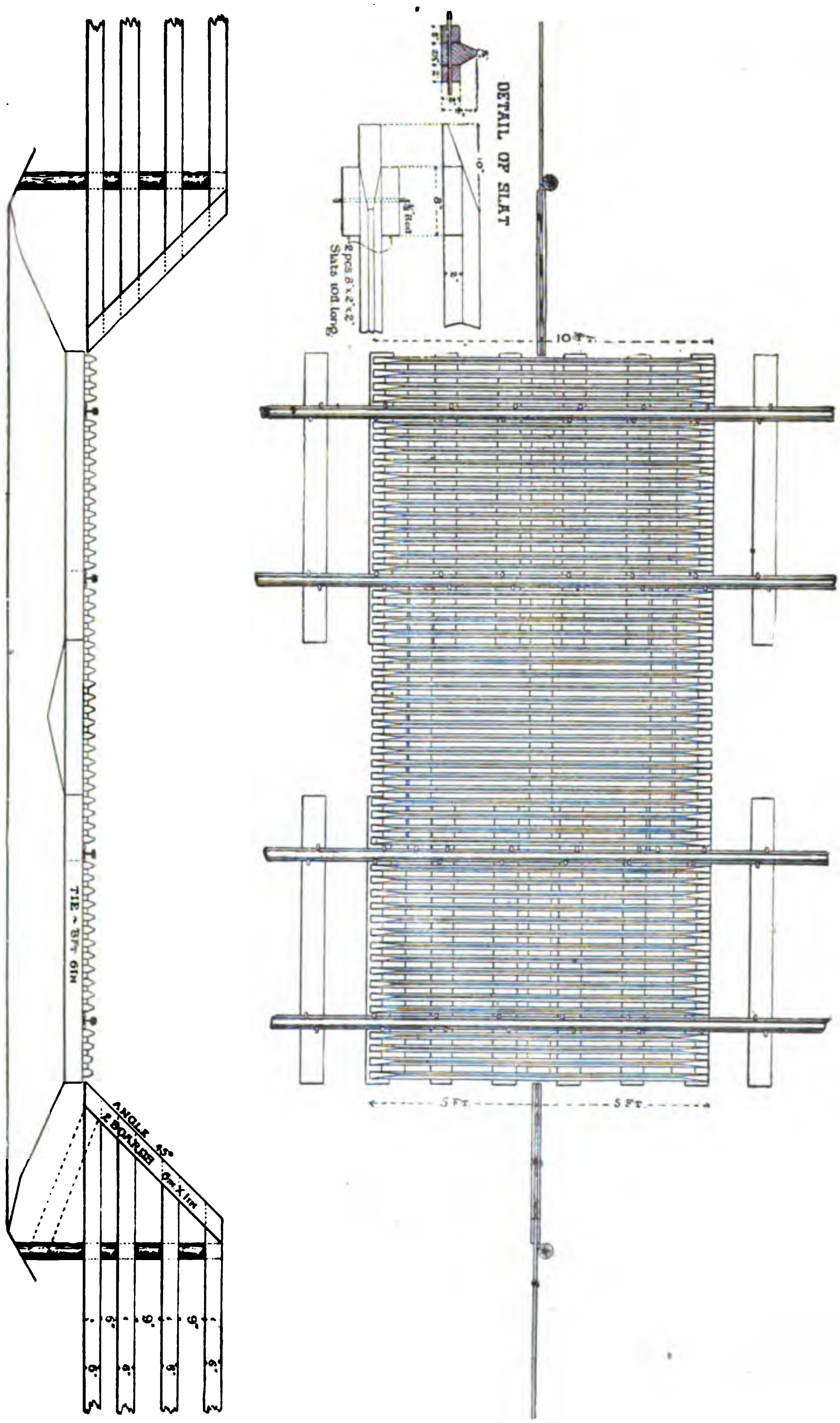


Fig. 99.—Slat Cattle Guard with Fences. (*See Page* 75.)

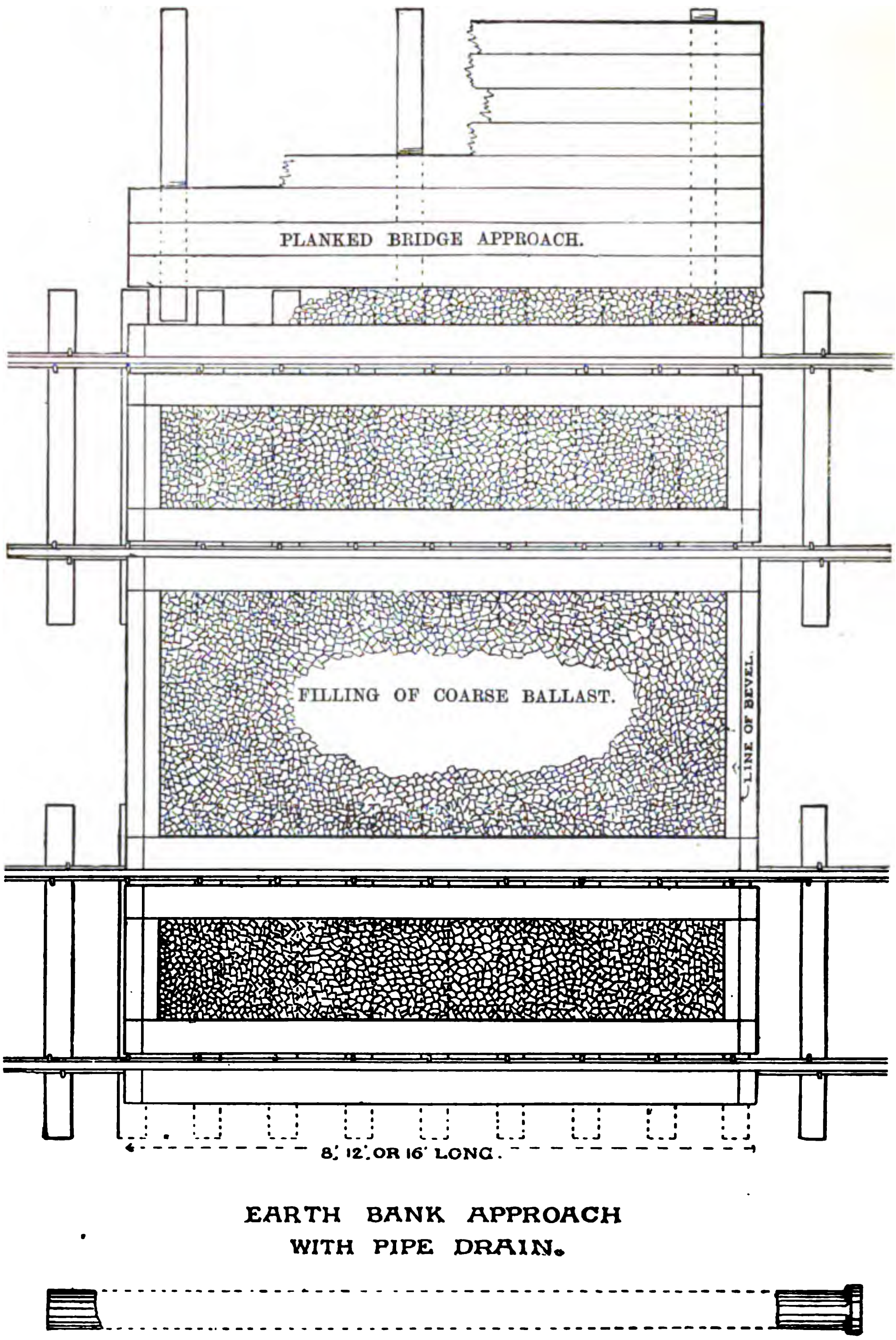
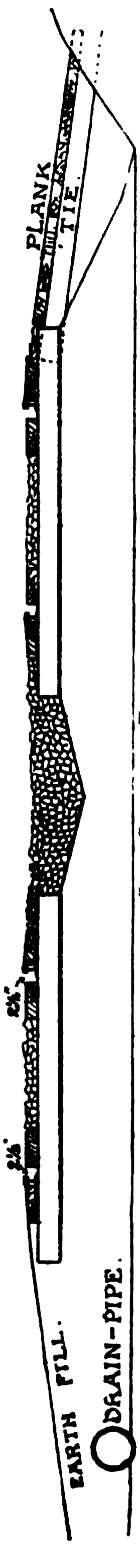


FIG. 101.—ROAD-CROSSING—BALLAST FILLING BETWEEN GUARD PLANKS.

On all roads there are needed a number of signs or warning signals, and as they are repeatedly used, it is well to have uniform styles by which to make them. Some of these signs are required by law while others are used as part of the system of operation. In designing them it should be remembered that they are intended for practical purposes, and therefore any attempt at elaborate ornamentation either by moulding or color is artistically false and out of place, besides reducing the signal's effectiveness and adding to its expense. The various signs should be made durable, of proper size, and in shape simple; the lettering should be large, clear and bold, and the colors black and white, unless some special point is to be gained by the change. In addition to the actual size of each of the signs, its height above base of rail, and the distance it is to be set out from the rail, must be determined for the sake of uniformity. The former of these demands a different length of post according as the sign is to be set up in a cut or on a bank.



CROSS-SECTION OF FIG. 101.

Unless specially noticed to the contrary it is recommended to set the signs 7 feet from the rail on banks and 8 feet in cuts, although these figures may frequently have to be modified by the configuration of the ground. These distances conform with road-bed cross-section of P. R. R. & N. Y., L. E. & W. R. R., previously illustrated.

The signs can be divided into three classes according as they are intended to govern the Transportation or Maintenance of Way departments, or are to warn outsiders. The following are the principal and most used examples, although there are others required for special causes. Fig. 102 represents a Mile Post, which should be stout and substantial, 10″ × 10″ in cross-section, and not less than 7 ft. 6 in. long, so as to permit its being set 3 feet in the ground and be 4 feet 6 in. above its surface. It should be painted white with distinct black figures painted on, or made of cast-iron and attached with screws according to the practice of Penn. R. R. For simplicity the top can be rounded over and covered with tin to protect the post from the weather. Since the mile post is used as a land mark and not as a warning signal, it should be set not less than 10 feet from the rail. In England the law requires half mile and quarter mile posts as well as mile posts, but in this country railroads are content with the latter subdivision.

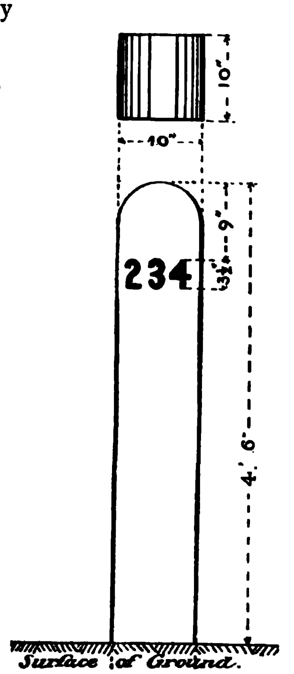


FIG. 102.—MILE POST.

"Whistle" and "Ring" posts. On approaching crossings State laws require the engine's bell or whistle to be sounded according to local

necessity. Since the law prescribes a point (generally about 1-4 mile from crossing) where to commence ringing or whistling, it is essential to mark this spot with a signal. Fig. 103 shows an appropriate design. The posts can be made alike, simply painting on the proper letter. In order to prevent their being mistaken for mile posts and to make them show clearly when the ground is covered with snow, the face of the post should be painted cobalt blue, with the letter white. The sides and back of the post are to be painted white.

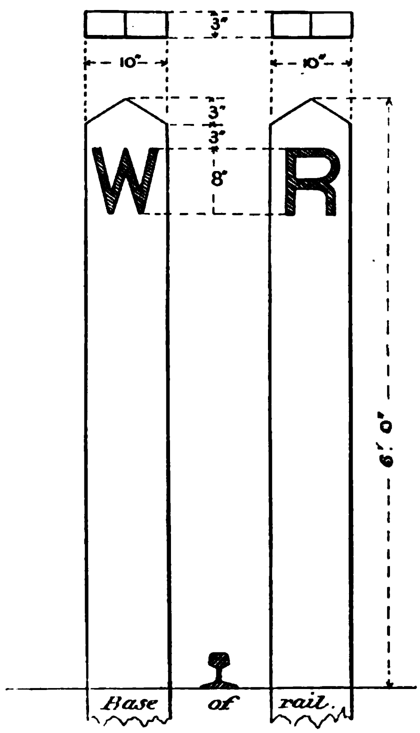


FIG. 103.—"WHISTLE AND RING" SIGN.

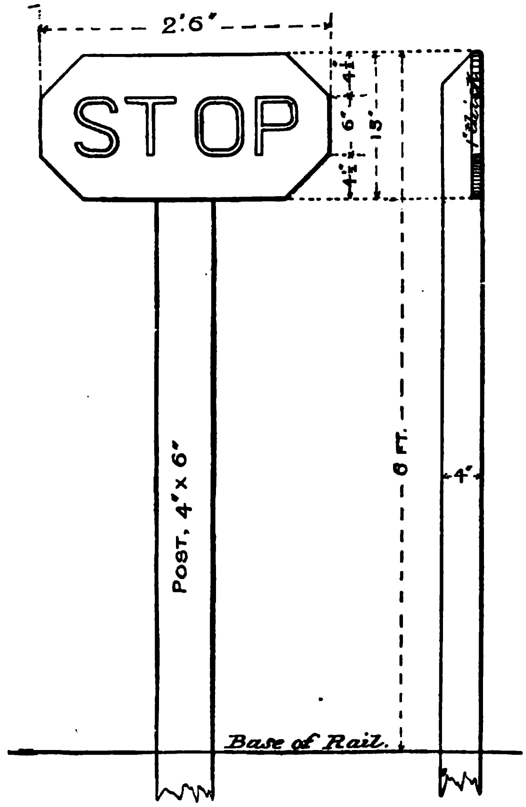


FIG. 104.—"STOP" SIGN.

"Slow" and "Stop" signs are required on approaching a grade crossing over another line, a draw-bridge, or any place where extra caution is required. These signs can be made similar according to Fig. 104, which gives full dimensions. The sign board is let into the post so as to be flush with its front and is fastened to it by 3-inch screws. For the "slow" signal the ground can appropriately be painted green, and for the "stop" painted red, these colors almost everywhere representing caution and danger. The letters and also the post should be white.

The limits of a yard, or the boundaries up to which switch engines can work without special orders, are usually marked by signs such as Fig. 105. The general construction is similar to the previously described "stop" sign, except that in this case the sign board and post are painted white with the letters in black.

The dumping of cinders on the track should not be allowed unless it is necessary to use ashes as ballast, and then it should be done only at stated places, denoted by

sign boards. Since the dumping grounds may be changed from time to time the sign should be of such form as to catch the eye readily. Fig. 106 shows suitable design. The board itself is composed of three boards 9 in. wide by 1 1-2 in. thick, which are halved together at the corners and held together, as well as to the post, by screws. The board and post are white with black letters 6 in. high.

In the Department of Maintenance of Way the principal sign is the one that defines section limits and which should be only large enough to properly answer the purpose.

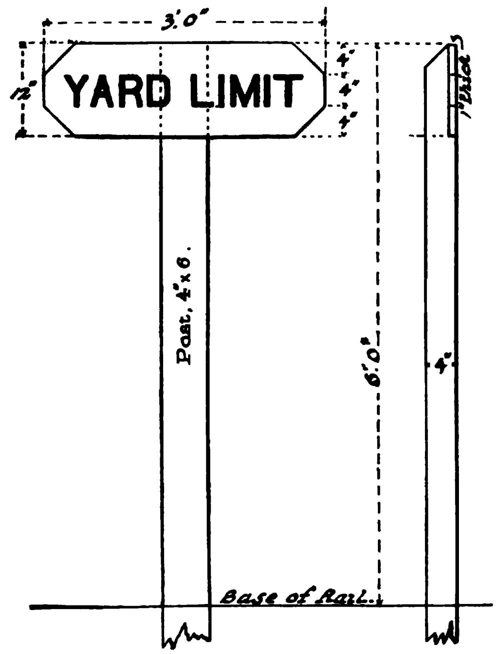


FIG. 105.—"YARD LIMIT" SIGN.

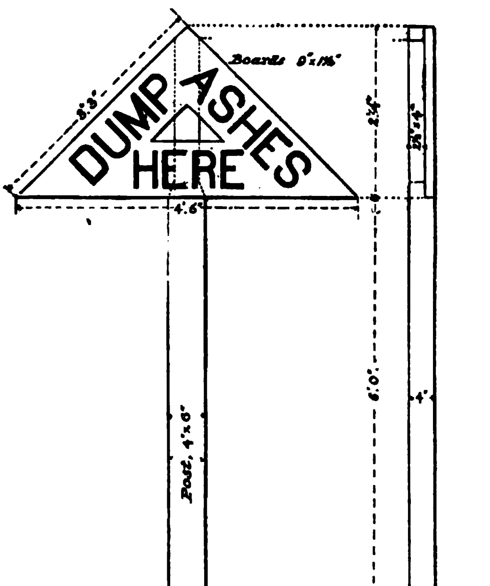


FIG. 106.—"DUMP" OR "CLEAN ASH PAN HERE" SIGN.

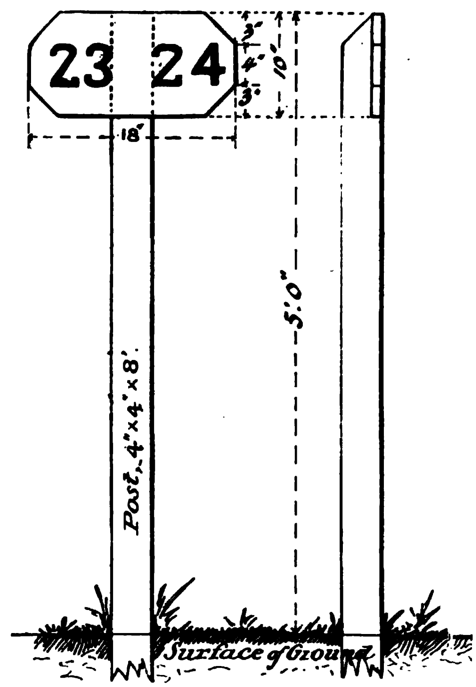


FIG. 107.—"SECTION" SIGN.

Fig. 107 shows a design meeting the requirements, the construction of which is similar to the "stop" sign. The post and back of the board are painted white, the face of the board black with white letters. This sign should be placed parallel with the track and 10 feet from the rail as it is of less importance than those of the first class and should therefore be less prominent. The Pennsylvania R. R. makes small signs like these of cast-iron.

Signs of the third class for the guidance

of outsiders are usually notices of danger or warning, such an one being required by law at all highways where they cross a railroad at grade. State Laws on this vary both as to inscription and size of letters. New York statute requires the wording as given in Fig. 108, with letters 9 inches high. This design is strong, economical and

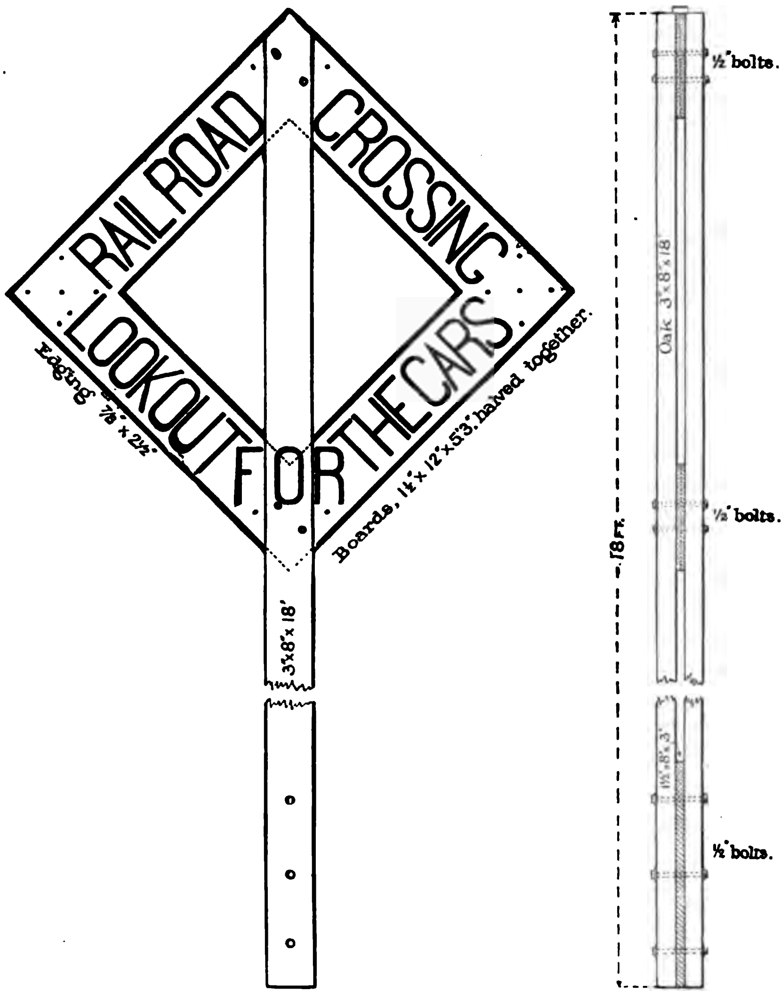


FIG. 108.—ROAD-CROSSING SIGN.

by its shape readily draws attention. The sign boards are made of 1 1-2 inch pine, 12 inches wide halved together at the corners, with strips 2 1-2 inches wide nailed on the outside and inside edges. These strips are added to give a finish and protect the exposed edges of the boards; they can, however, be omitted to save expense. The post is composed of 2 pieces of oak, 3 inches by 8 inches by 18 feet; at the bottom there is a filler 3 feet long, while the sign board separates the parts at the top. The whole arrangement is secured by 1-2 inch bolts. The sign-boards must of course be painted and lettered on both sides. The background and post are white, while the letters and sides of the moulding strips are black. The sign should be firmly set in the ground at least 3 1-2 feet. The edges of all these posts can be champered

if desired. It improves the general appearance and protects the corners from being splintered by blows, but adds to the cost.

In connection with the above there is a miscellaneous class of devices that can be appropriately discussed. Fig. 109 shows a Bridge Guard or "Tickler." Many

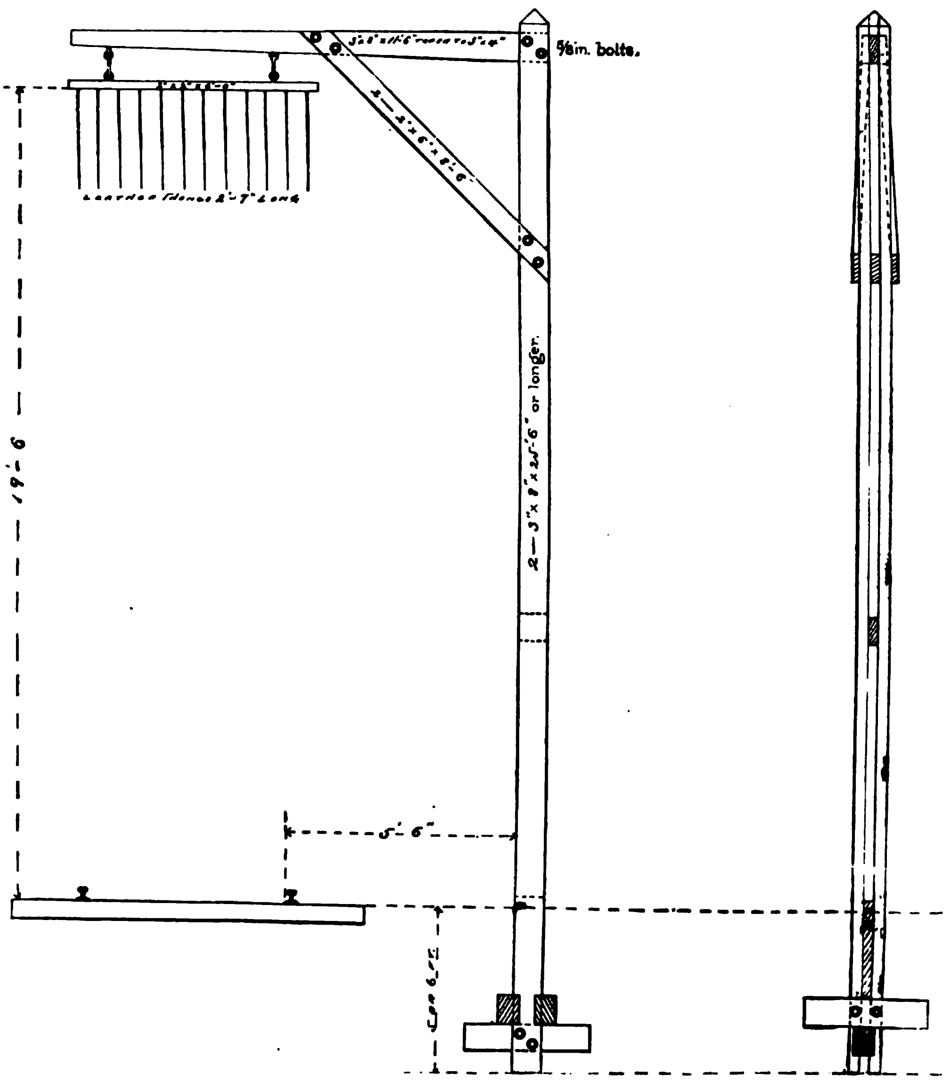


FIG. 109.—BRIDGE TELL-TALE OR TICKLER.

box-cars now in use are nearly or quite 14 feet above the rail, therefore all bridges, tunnels, or structures across the track should be elevated to a clear height of 20 feet, so as to permit a man to stand on one of such cars and not be struck; structures not high enough should be protected by these "Guards" as warning signals. Those most generally used have ropes for the pendants. But these ropes in winter get frozen stiff and are capable of giving quite a severe blow. Better to use leather which at all times will strike hard enough to draw attention without hurting the person warned. The method of attaching the straps to the arm prevents any of them, or the set as a whole, from being caught above and so rendered useless.

Fig. 110 is a simple design for a bumping block adapted for sidings where it will not be used hard. It consists merely of two ordinary rails with one end upturned. Resting against this upright, and framed down over the head of the rail is a stout block of timber about 6 feet long. The bent rails, which are connected in the ordinary manner with the track, should be of steel, as iron will break at the bend if struck with force. Such a block is damaging to car trucks if they come against it energetically, but nevertheless it answers very satisfactorily wherever a cheap and efficient bumper is required. For heavier work the apparatus given in Fig. 111 is better. The arrangement of the parts and the method by which the weight of the track, together with the car itself, are used to add to the resisting force are clearly explained by the diagram.

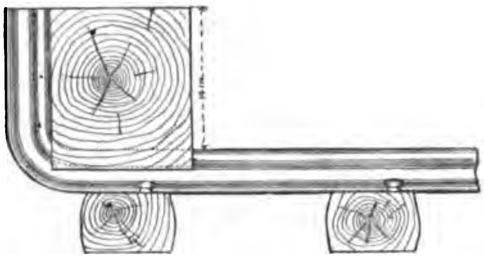


FIG. 110.—BUMPING BLOCK

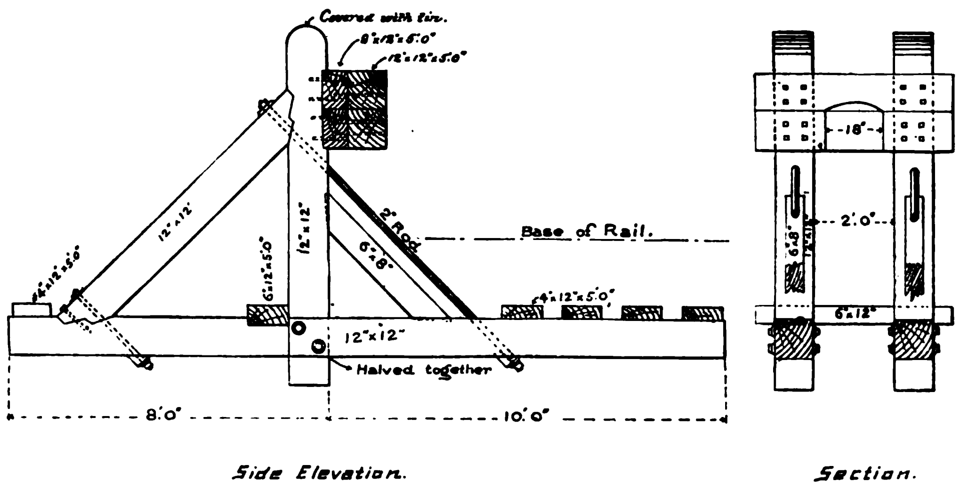


FIG. 111—BUMPING BLOCK.

MAIL CRANE

Of mail cranes there are a great many varieties, but the one shown in Fig. 112 has substantial claims for efficiency, durability and simplicity of construction. At the side there are steps to permit one to mount to attach the mail pouch to the arms. The braces are secured at top and bottom by lag screws, while the mast at the bottom is framed down to 3 in. by 3 in. and let into the sills, and these latter are held to the ties by lag screws. The length of the mast depends on arrangement of mail car, while the distance it is from the rail varies according to length of arms and width of car; with the average width of car and length of arms as shown this distance would be about 7 feet.

The great point in favor of design of Fig. 112 is that it rests on two long ties and becomes really part of the track instead of independent of it, as is usually the case. Thus when the track heaves in winter, the mail crane goes with it, and trackmen in

performing regular repairs can not throw it out of adjustment. To set a crane, a right angled gauge should be used, one arm of which sets down over the rails and the top end of the upright part so adjusted as just to touch the end of the upper crane arm when revolved into position.

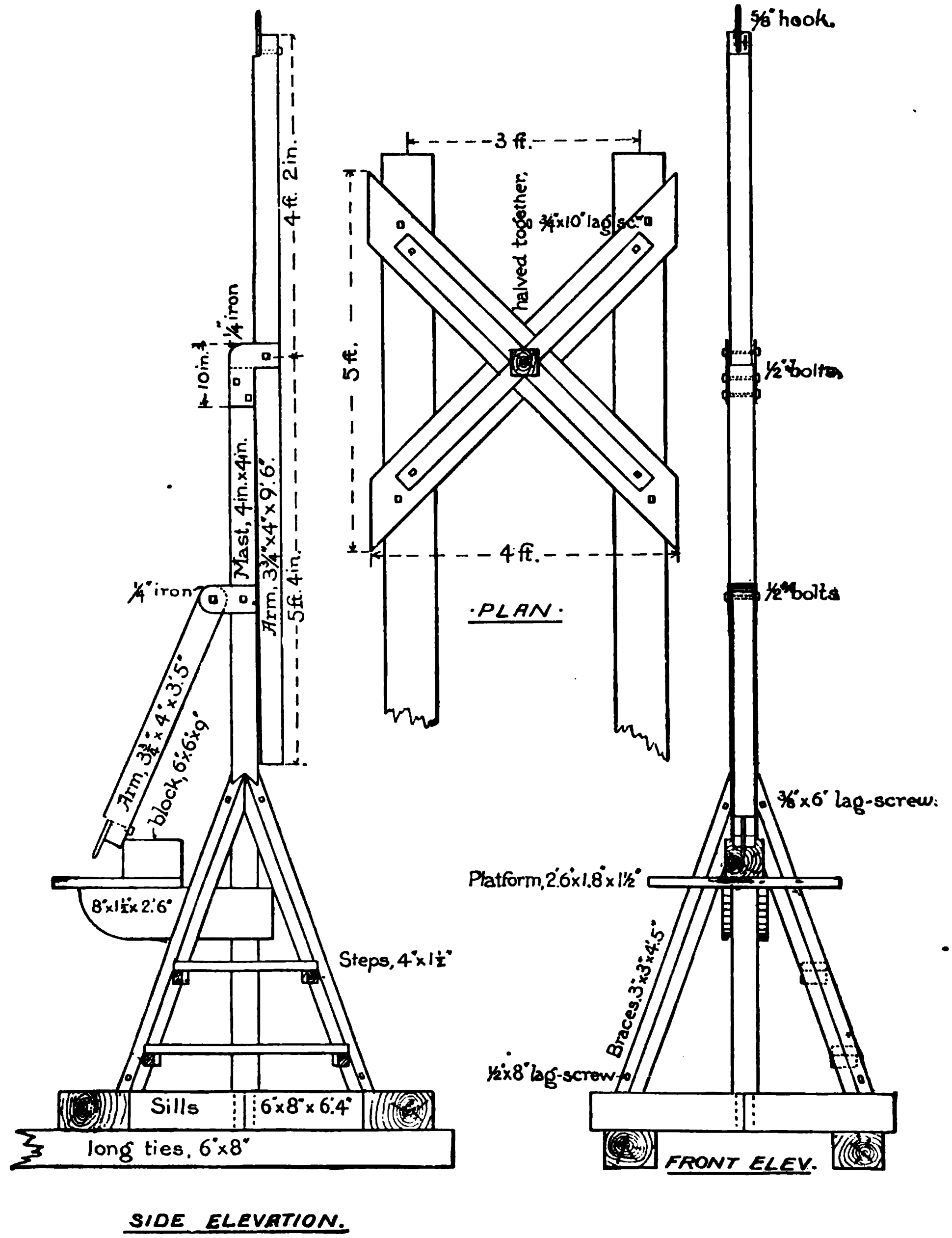


FIG. 112.—MAIL CRANE.

BUILDINGS.

The buildings which specially belong to the Track Department are usually three: Tool or Section Houses, Flagman's Cabin and dwelling "Shanties." Of the first the re-

quirements are that it shall be large enough to hold the handcar, tools and supplies, and leave sufficient room for the men to move about. It is best to have the house stand parallel with the track to permit the door to slide; and also to give easier entrance when the car is run in. The door should slide, and not open on hinges. Full details with dimensions of a conveniently arranged house are shown on the plan, Fig. 113. It is preferable to have the house set next to a side track rather than the main track, so that the men can take their car in and out without interfering with trains. The house should be set back far enough from the track to permit the hand-

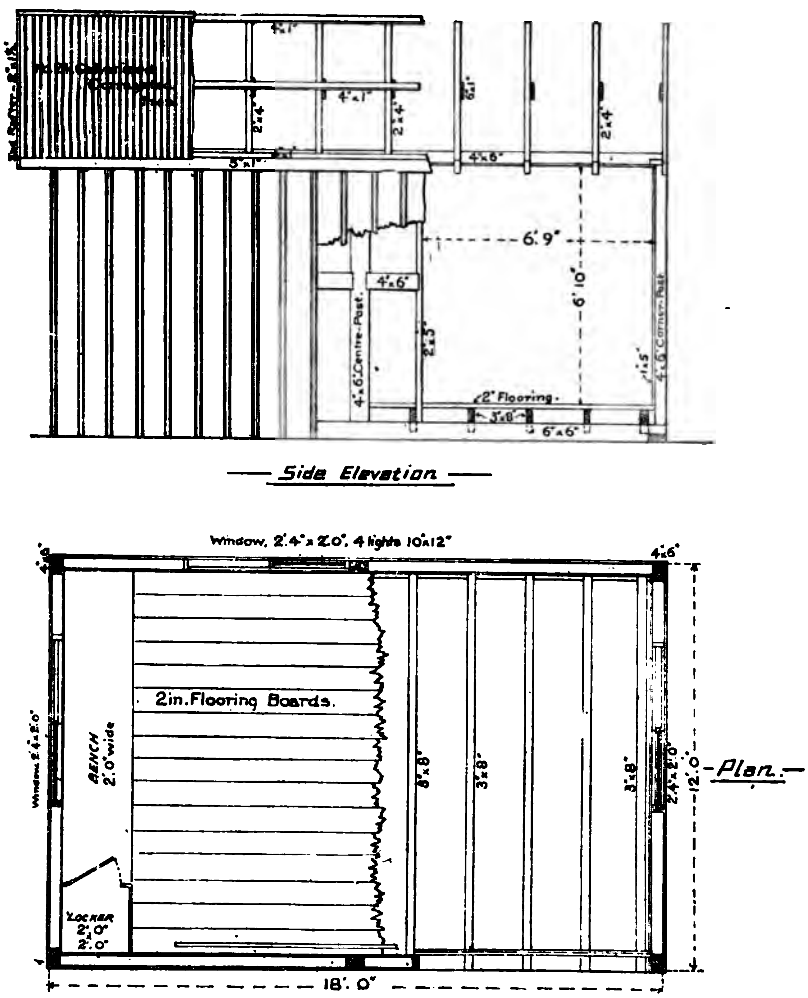
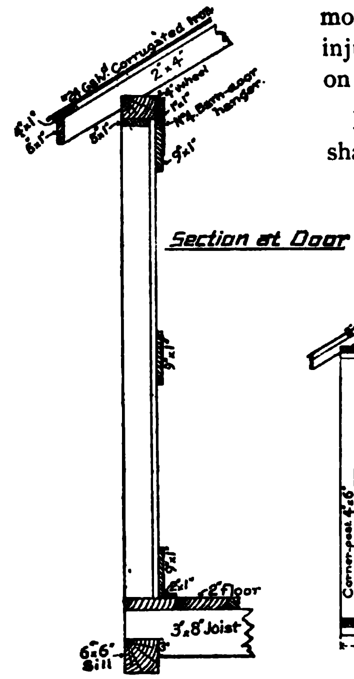


FIG. 113.—TOOL HOUSE.

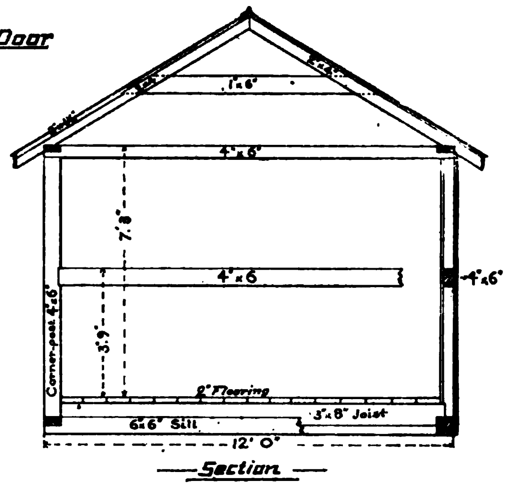
car to stand between the house and rail without danger of being struck by passing trains.

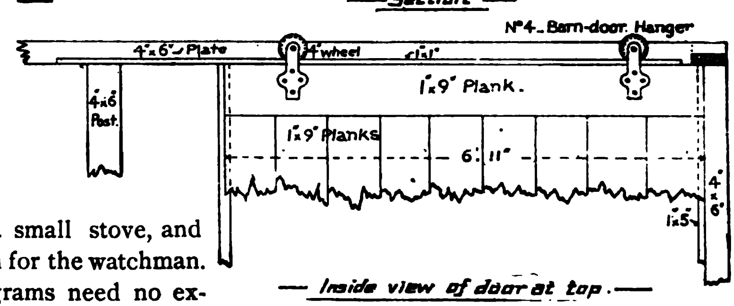
The arrangement shown in Fig. 114 is a sort of turntable which trackmen themselves generally make as an easy method of transferring a car to and from the rails. The frame is portable and is set down on the block (into which the pivot pin passes); the car is then run up on it, when it can be easily revolved. This saves time, but



more especially saves the car, for which nothing is more injurious than the severe handling it gets when it is lifted on or off the rails.

Fig. 115 (See p. 90.) is a set of plans for a watchman's shanty. The building should be large enough to accom-





Details of Tool House.

modate a small stove, and give room for the watchman. The diagrams need no explanation except to notice that the roof (as also that of the tool house) is of corrugated iron instead of ordinary shingles, in order to reduce the chances of fire.

For a dwelling shanty there is needed an economical, yet comfortable building, capable of accommodating a family. This idea seems to be realized in the plans shown in Fig. 116. The construction is simple, the building being made with a "balloon" frame. Down stairs there is a kitchen, pantry, sitting-room and two bedrooms, while upstairs there is an attic

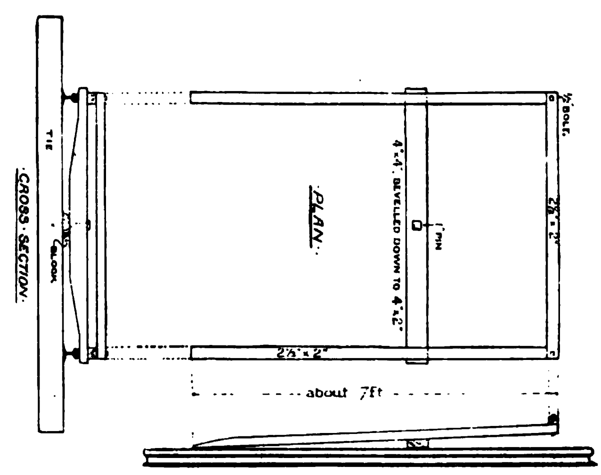


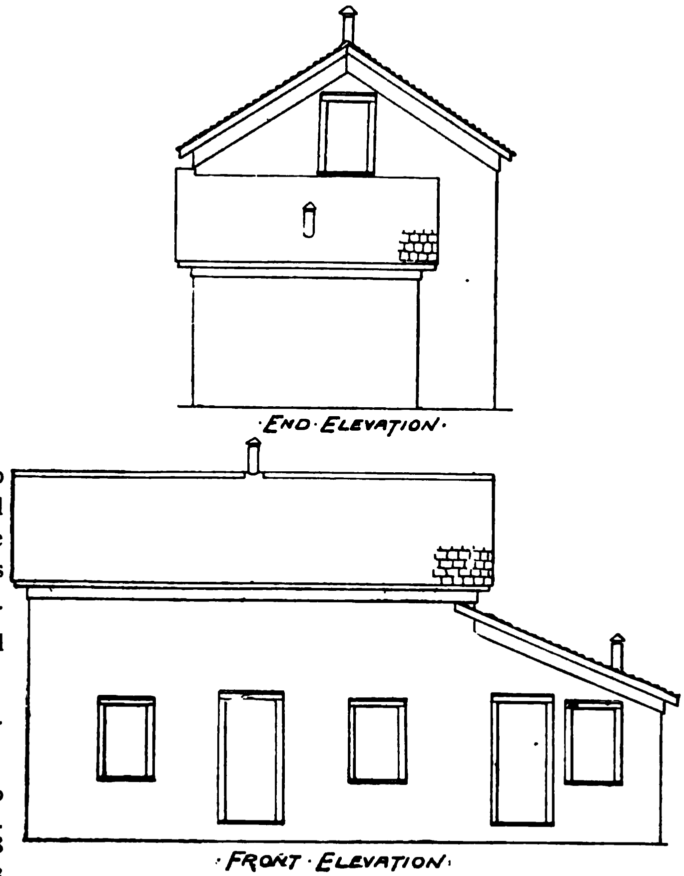
Fig. 114.—Handcar Transfer Frame.

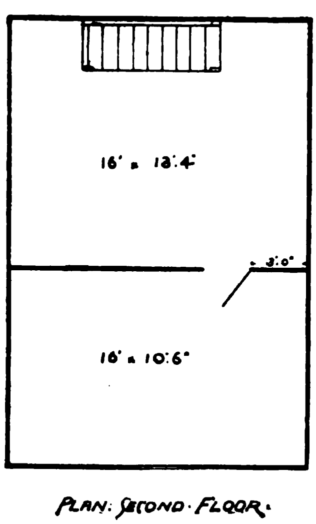
which can be cut up into two bedrooms, and a storeroom over the kitchen. The rooms are all well lighted.

Appended is a bill of materials:

Pine, -	672 ft. B. M.
Oak, -	8 " "
Hemlock,	9234 " "
Pine shingles, -	6000
Nails, -	242 lbs.
Win'ws (12 l'g'ts 8x10)	8
Locks, - -	2
Latches, - -	6
C'rp'n'r's labor,	46 d'ys
Painter's "	3 "
Butts, -	10 pair
Door knobs, -	2
Hinges, -	1 pair
Sash bolts, -	1 doz
Screws, -	27 "
Paint (dry m't'l'c)	50 lbs
Oil, - -	12 gals
Japan dryer,	1 "

An excellent color for all these buildings is a dark red.





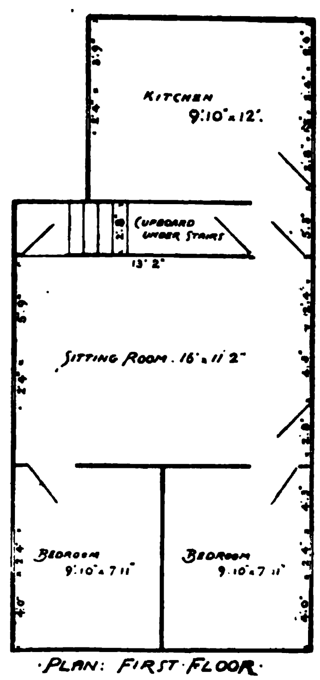
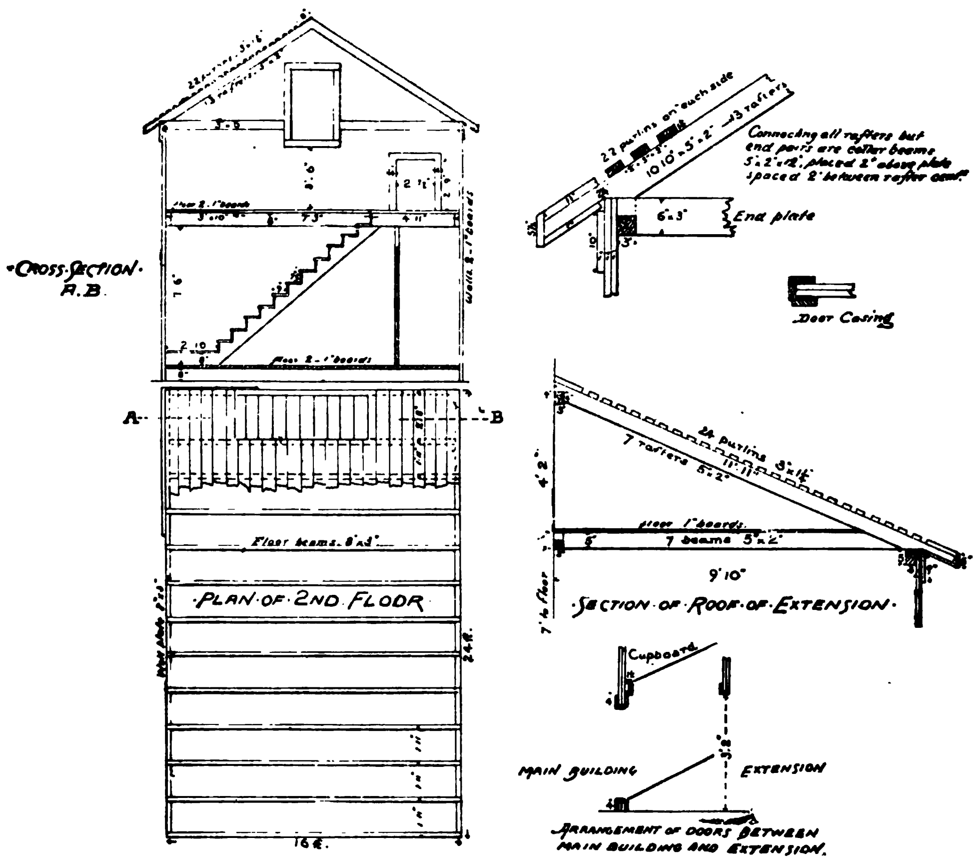
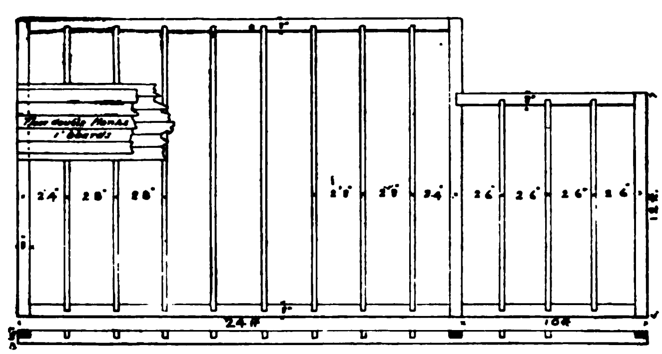


FIG. 116.—DWELLING SHANTY.





FIRST FLOOR BEAMS

FIG. 116.—DWELLING SHANTY.

NOTE: To accompany Fig. 116.

Doors. The two exterior doors to be 2 ft. 8 in. wide; 6 ft. 8 in. high. The six interior doors to be 2 ft. 6 in. wide and 6 ft. 6 in. high.

Windows. Of two sashes; lower 2 ft. 4 in. by 2 ft.; upper 2 ft. 4 in. by 1 ft. 11 in. Bottom of lower sash, 2 ft. 4 in. from floor.

Casings of doors and windows to be of pine, 4 in. by 1 in.

Thresholds of doors and *Sills* of windows to be of oak 4 in. by 2 in.

Walls and *Partitions* to be double boarded with 1 in. boards.

Stairs. 11 steps—12 risers $7\frac{1}{2}$ in.—11 treads 9 in.—the large step 2 ft. 10 in. by 2 ft. 8 in.—8 in. rise. Stairs, 2 ft. 8 in. wide.

Railing at head of stairs: 2 posts, 3 ft. 3 in. by 5 in. by 2 in.; 2 rails, 7 ft. 3 in. by 4 in. by 1 in.; 2 rails 2 ft. 9 in. by 4 in. by 1 in.

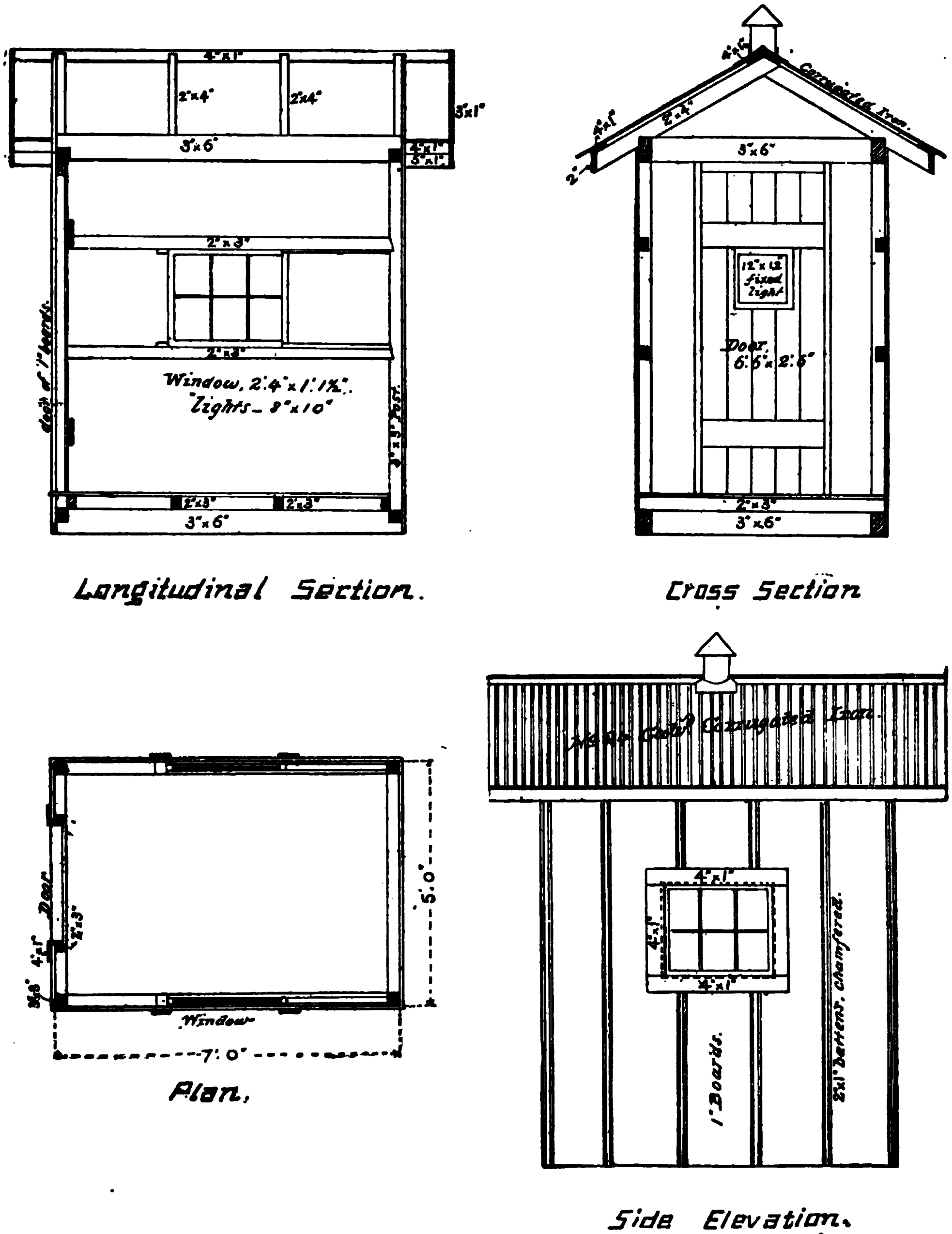


FIG. 115.—WATCHMAN'S SHANTY. (*For Description see page 87.*)

CHAPTER VI.

GAUGE—LINE—SURFACE—CENTRIFUGAL FORCE—SUPER-ELEVATION—WIDENED GAUGE—TRACK WORK ACCORDING TO SEASON—DISTRIBUTING AND REPLACING TIES — BALLASTING — TAMPING — LEVEL BOARD—ADJUSTING CURVES — SHIMS—DITCHING—HANDLING RAILS—GRASSING—SNOW.

GAUGE, LINE AND SURFACE.

The three essential properties of good track are correct gauge, line and surface. The proper distance between the rails must be exactly preserved everywhere except on sharp curves, where it is to be evenly increased as will hereafter be explained. An allowance of 3-4 inch is made in the wheel gauge which is sufficient for easy clearance, and allow the truck to be properly guided without swaying, while if the gauge of the track is wide, and especially irregular, the trucks are no longer restrained and a disagreeable lateral motion is imparted to the train damaging both to it and the track.

Some trackmen prefer to contract a gauge at frogs and on bridges with a view of reducing to a minimum the lateral play of the trucks. As was mentioned before in respect to frogs and is repeated now for bridges, this is unnecessary. If the track is of the proper gauge the 3-4 inch allowance in wheel gauge is not sufficient to produce an injurious side motion. On the other hand such contraction produces irregularities in alignment and depreciates in the minds of trackmen the value of the gauge as an exact instrument. Unless the gauge is uniformly correct, perfect alignment is impossible. Wherever the track is out of line a lateral blow is given by the train, which, repeated by each wheel of every train, keeps on forcing the track more and more out of place. Car springs are so arranged as to either destroy or greatly reduce the shocks of vertical irregularities, but there is no commensurate allowance made to soften the defects of line. Though the error of alignment be ever so small, each wheel as it meets the deflection is violently thrown laterally, producing in the car, to the discomfort of its occupants, those sharp, quick swings, apparently almost the result of a blow. Therefore, true alignment is a necessity, and to obtain it, our gauge must be exact, so that both rails shall be true. Correct alignment is so important that on all roads ambitious for a perfect track it should be marked by permanent monuments set, say, every 300 feet on curves and every 500 to 1,000 feet on tangents. With track which is out of line and which is to be put in shape, the correct line should be given by transit plugs set not over 100 feet apart. Mark the center of a track gauge by driving a nail through it, and throw the track until the point of the nail is over the tack in the plug. Repeat this operation at each of the plugs and line between them by eye. If the track it double, set stakes for the center of one track only, then after that is lined throw the other to correspond by means of a long gauge adjusted to fit the clear space between the two inside rails. By these means, track is more quickly, easily, and of course more correctly lined, than can be done by a track foreman's eye.

If one rail is lower than the other or is uneven in itself, (for track can be out of surface both transversely as well as longitudinally,) the depression will cause the truck to lurch down, and the blow or pressure thus given not only increases the trouble but also forces the track out of line. Gauge, line and surface are thus mutually related, so that an error in one soon leads to an error in the other two. To avoid those very disagreeable sensations of a car inclining, or the still worse rolling, oscillating motions, the vertical surface of each rail must not only be kept true, but the tops of the two rails must be in the same horizontal plane. To obtain this a constant use of the spirit level must be insisted upon. Track should never be worked over without keeping the level across the rails and noticing that they are level horizontally when on a tangent.

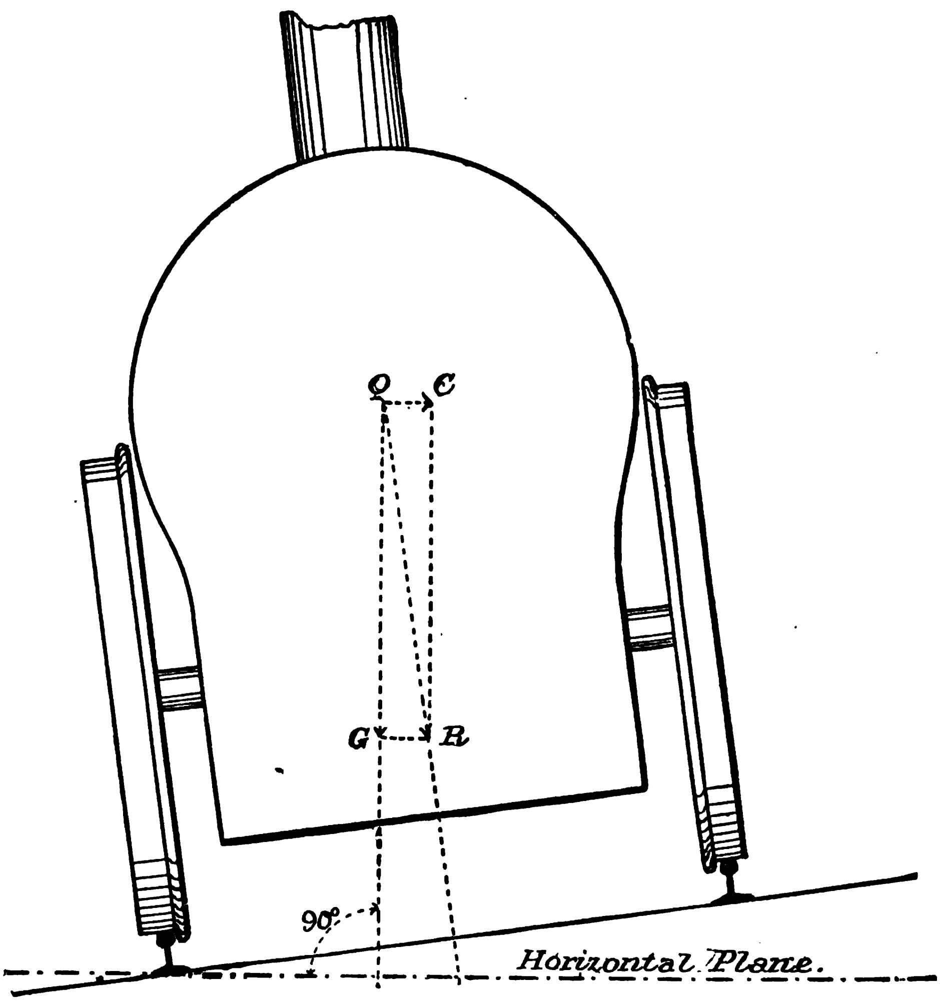


FIG. 117.—ELEVATION OF OUTER RAIL.

CENTRIFUGAL FORCE.

On curves the rails are no longer in the same horizontal plane, since the outside rail is elevated to compensate for the centrifugal force developed in the train. It is necessary to compensate for this force, because, acting in the direction of the radius, it throws the wheels against the outside rail, producing not only greatly in-

creased wear of that rail but also greater flange friction, adding extra work to the engine. If all the weight of the train were on a level with the rails, these would be the only reasons for super-elevation, but since the center of gravity is elevated above the rails about 4 1-2 to 5 1-2 feet in engines, and 8 feet in passenger cars, centrifugal force tends not only to press the wheels against the outside rail, but also to cause the cars to revolve about that rail as a center. This produces in proportion to height of center of gravity the unpleasant tipping of a car toward the outside, experienced when passing around a flat or insufficiently elevated curve. Let Fig. 117 represent a skeleton cross-section of an engine where O is the center of gravity, O C the centrifugal force acting horizontally, and O G the direction of the weight due to gravity acting vertically. When the radius of the curve is infinity, that is, a tangent, O C is zero and O G is perpendicular to the horizontal plane of the rails. As the curve increases the centrifugal force becomes more and more sensible since an expression of its value is

$$\text{centrifugal force} = \frac{\text{Weight} \times (\text{velocity})^2}{32.2 \times \text{radius}}$$

and the body is acted upon by the two forces. In order to balance this horizontal component, the plane of the rails is inclined so that the direction of the resultant or of the two forces will still be perpendicular to it, as was the direction of the weight alone when the centrifugal force was zero.

SUPER-ELEVATION.

Knowing the speed and the radius of the curve the proper elevation can easily be calculated by the following formula:

$$\text{elevation} = \frac{d\,V^2}{32.166\,R.},$$

where d denotes properly the distance between rail centers, considering them as the bearing points, although d is usually taken as the gauge; V denotes the speed of the train in miles per hour, and R the radius of the curve. It will thus be seen that the elevation increases as the square of the speed of the train, that is, to double the speed requires four times the elevation.

Results calculated for speeds varying from 10 to 60 miles per hour, and curves from 1° to 20° are given in Table No. 7 (page 94), where the elevation and speed is given in inches and fractions.

Unless the traffic is all operated at about the same rate of speed, or the freight and passenger trains are run on separate tracks, it is impossible to adjust the elevation to suit all velocities, especially as they are liable to vary within such wide limits, and the question arises whether it is advisable to set the curves up for the fastest trains or to select some average rate as the standard. Unless the freight interest greatly predominates, the former is preferable: first, for the sake of the train itself, because the fastest trains are those which should be favored most; second, for the comfort of the passengers, because the disagreeable sensations of a flat curve are in proportion to the square of the speed; third, for the saving of the track, because in this same proportion is also increased the power of a train to injuriously affect a curve by throwing it out of line, unless it is set up to its rate of speed. The use of this table necessitates the knowledge of the degreee of each curve, information which is not always obtainable, but since the lack of proper elevation can easily be detected by a person rid-

ing either on the engine or on the rear platform of a train, whose speed is the standard, a good every day rule for roads where the degrees of curvature are not known is "to put the curves up till they ride right." But if, previous to the beginning of the work of elevating a curve, there is doubt as to what is right, the old and practical method of stretching a cord between any two points on the inside of the outer rail and measuring its middle ordinate can be used. The formula for this (taken from Searles) for 4 feet 8 1-2 inch gauge is

Length of string = 1.587 V

By substituting in the place of V the speed of the fastest train, the result will give the length of string required. For forty miles per hour the length is 63 1-2 feet. Of course, to use this method, the curve must be in line, or else several measurements must be taken in order to get a fair average. The most satisfactory way is to know the degree of curvature and to take the proper elevation from the table. For the benefit of the trackmen the degree of the curve can be marked on the telegraph poles nearest the points of curve and tangent.

Table No. 7.

Degree Curve.	Miles per Hour.										Degree Curve.
	10	15	20	25	30	35	40	45	50	60	
1	1/16	3/16	1/4	7/16	5/8	13/16	1 1/16	1 3/8	1 11/16	2 1/2	1
2	1/8	5/16	9/16	7/8	1 1/4	1 11/16	2 3/16	2 3/4	2 7/16	4 15/16	2
3	3/16	1/2	13/16	1 5/16	1 7/8	2 1/2	3 5/16	4 1/8	5 1/8	7 3/8	3
4	1/4	5/8	1 1/16	1 11/16	2 1/2	3 3/8	4 3/8	4 9/16	6 13/16	9 3/4	4
5	3/8	3/4	1 3/8	2 3/8	3 1/16	4 3/16	5 7/16	6 7/8	8 1/8	12 1/16	5
6	7/16	15/16	1 5/8	2 9/16	3 11/16	5	6 9/16	8 1/4	10 1/8		6
7	1/2	1 1/16	1 15/16	3	4 5/16	5 7/8	7 5/8	9 9/16	11 3/4		7
8	9/16	1 1/4	2 3/16	3 7/16	4 15/16	6 11/16	8 11/16	10 7/8			8
9	5/8	1 3/8	2 1/2	3 13/16	5 1/2	7 1/2	9 3/4	12 3/16			9
10	11/16	1 7/16	2 3/4	4 1/4	6 1/8	8 5/16	10 3/4				10
11	3/4	1 11/16	3	4 11/16	6 3/4	9 1/8	11 13/16				11
12	13/16	1 7/8	3 5/16	5 1/8	7 5/16	9 15/16	12 11/16				12
14	15/16	2 3/16	3 13/16	5 15/16	8 9/16	11 3/4					14
16	1 1/16	2 1/2	4 3/8	6 13/16	9 15/16						16
18	1 1/4	2 3/4	4 15/16	7 5/8	10 7/8						18
20	1 3/8	3 1/16	5 7/16	8 1/2	12						20

It is not necessary to elevate very sharp curves at the same rate as those of longer radius, because it would give a very excessive amount for slow trains, and it is not demanded by the fast trains, as their rate of speed would be naturally decreased on passing round a heavy curve. Thus, in addition to deciding on a rate of elevation per degree of curvature it should also be decided at what radius this rate can be diminished, and what should be the extreme limit of the allowable amount of elevation. These three questions depend on conditions of traffic and ruling curvature, but in general it is well to begin and diminish the rate after curves of 5° or 6°, and to have no elevation greater than about 8 inches, which is equivalent to a 10° curve at 35 miles per hour.

The elevation at the point of a curve should be as great as at any other part, and in order to avoid an abrupt shock, the elevation is gradually run out on the tangent. Experience, which must be our best guide in this matter, shows that about 50 feet for each inch of elevation gives very satisfactory results both for running on and running off the curve. Instead of elevating the tangent, and also to ease the approach to the curve, the curve can be gradually flattened or continuously compounded towards the point, and by keeping the elevation in accord with it, the curve and elevation can be run out together. The methods of doing this are clearly set forth in "Spiral Curves" by Searles, to which the reader is referred. Very excellent results are obtained by this practice, but it necessitates the curve being laid out by a transit and marked with permanent monuments, or else the trackmen will soon destroy the accuracy of the work.

It is not to be thought, however, that elevation will entirely take away the wear of the outside rail, for that rail still has to resist the tendency of a train to go straight ahead, that is, it must do the guiding. So at all speeds, the wheels will be found pressed against the outside rail, even in the center of a long freight train, where it might be expected to find the wheels drawn down against the inside rail, by considering them as links in a chain which the power at one end would tend to draw into a chord of the curve.

As to position of both wheels of a truck, the leading wheel of course is the one which is guided, but this very action of turning it slews the truck, if running true, so as to bring the rear wheel also bearing against the outside rail, though probably with diminished pressure. With engines the case is slightly different, for with their longer wheel base and greater weight they are not so easy to throw. At low speeds the trailing drivers probably run loose, that is, not pressing against either rail, and the tendency to press against the outside rail increases with the speed and degree of curvature.

The turning over of the inside rail and cutting into the ties along the outside edge of the flange has formed a basis for the belief that wheels at low speeds or at speeds less than that for which the curve is elevated, press against the inside rail; but a moment's consideration of the principle stated above, that the outside rail is the guiding power, will show that the wheel flanges press against the outer rail. If this does not suffice then it is only necessary to watch a few freight trains drag around a curve and note the wheels pressed against the upper rail, or else to examine the inside rail of a curve and to find the comparative absence of flange wear on the side of its head, unless it be a very sharp curve with contracted gauge.

Now this turning over is due to the fact that the lateral component of gravity is greater than its centrifugal force (See Fig. 117) so that the resultant, instead of being vertical to the plane of the rails, makes an acute angle and is deflected toward the inside of the curve, bringing on that rail not only greater weight than its due (one half the load on the axle) but that increased weight with a lateral thrust. This lateral thrust is augmented by the normal at the point of contact of the rail and wheel tread being directed outwards instead of vertically, due to the curved surface of the former and the coning of the latter. On the other hand when speed is greater than is allowed for in the super-elevation, the resultant passes obliquely through the outside rail and tends to turn it over. These effects are counterbalanced in England and Europe generally by inclining the rails inwardly so that the weight can be transmitted vertically through the web.

The loss of tractive power of an engine by the resistance of a curve is due to three causes. First, the friction pressure of the outside rail against the wheel flanges in guiding the truck around the curve, which friction increases with the speed and degree of curvature, added to the friction of additional pressure developed by centrifugal force, unless properly elevated. Second, the raising of the entire weight of the train through one half of the elevation. Third, unless properly elevated the resultant OR passing further from one wheel than the other produces diminished adhesion on that side. The extra work of the second cause is saved in Europe by lowering the inside rail below grade one half the elevation required and by raising the outside rail the same extent, thus not affecting the center of gravity of the train. This refinement, however, is not practised in this country.

WIDENING GAUGE.

Stress was laid above on requiring track on tangents to be spiked to exact gauge, but with curves the conditions of the case are somewhat different. The wheel base of a truck is rigid, therefore it is evident that as curvature increases the play of the wheel gauge is decreased until finally a curve is reached when the outside rail will bind on the extreme outer edges of the flanges, and the inside rail will press against the flanges of the opposite wheels where they are nearest to each other. But we need not concern ourselves with calculating the widening of the gauge necessary for ordinary car trucks or any short wheel base, but consider that class of rolling stock whose wheel base and arrangement of wheels is most trying. According to the general practice at present this is the "consolidation" engine with its four drivers on a side connected, although there are in different parts of the country a few engines designed for special purposes, with five wheels connected. Fig. 118 gives a diagram of the "Erie consolidation" which can be taken as typical of the class. The diameter of the wheel is 4 feet, and with the flange 1 1-8 inches deep it gives the chord of the arc of the flange below the top of the rail to be 1 foot 2 7-8 inches.

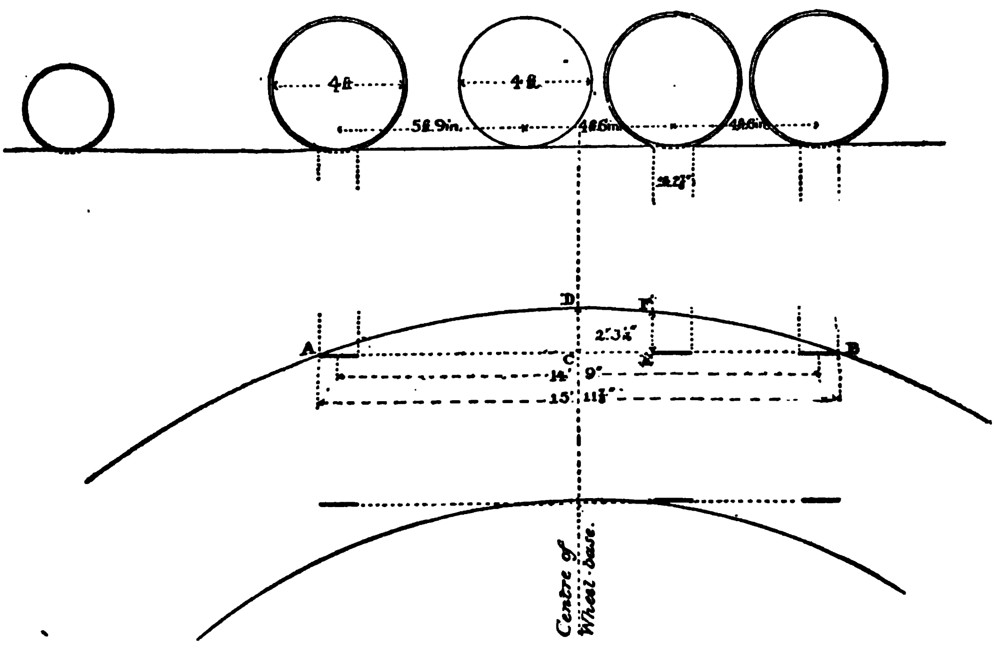


FIG. 118.—DIAGRAM OF WHEEL-BASE "CONSOLIDATION" ENGINE.

The lower part of Fig. 118 shows a plan of the flanges of the drivers which are below the top of the rail. The engine is supposed to be standing on an exaggerated curve and the gauge to be such as just to bind, that is, the outside rail touching the front edge of the flange of the forward driver and the rear edge of the last driver. Now, if there were a central wheel or if the dotted line indicating the gauge line of the flanges were solid, it is evident that the inside rail would be tangent to this line at its middle point. The further the nearest wheel is away from the center the closer the rails can be set, that is, the less distortion from correct gauge is required. With the engine in question the nearest wheel to the center is the second driver, but the flange is omitted from this wheel, so that the nearest point of obstruction is the flange of the third driver, and the front edge of this is the one that binds.

It may be incidentally mentioned that a series of experiments were conducted some years ago to determine, with wheels spaced as above, from which the flange could be most advantageously omitted, and driver No. 2 was selected. The reason of the result is here shown. The dotted lines represent the wheel gauge, and by determining the distance $E\,F$ we find what the gauge of a curve with given radius should be so as to produce the effect as indicated, and by adding three quarters of an inch to this we obtain the track gauge with the same clearance as on a tangent. Properly $E\,F$ should be measured radially, but the error in measuring it perpendicularly to the chord, $A\,B$ is inappreciable.

$$\text{The middle ordinate } C\,D \text{ (closely approx.)} = \frac{(\text{chord}^2)}{8 \times \text{radius},}$$

and neglecting the odd inches, (the omission increases result) the ordinate $E\,F = \frac{15}{16}\,C\,D$. Calculating this to the nearest $\frac{1}{16}$ inch for each degree of curvature from 1 to 10, and tabulating the results gives Table No. 8.

Table No. 8.

Degree of Curve.	Ordinate E F.
1	$\frac{1}{16}$
2	$\frac{1}{8}$
3	$\frac{3}{16}$
4	$\frac{1}{4}$
5	$\frac{5}{16}$
6	$\frac{3}{8}$
7	$\frac{7}{16}$
8	$\frac{1}{2}$
9	$\frac{9}{16}$
10	$\frac{5}{8}$

An inspection of this table shows that the required increase of gauge is not as great as is currently believed among trackmen, who always increase gauge excessively, and furthermore that even with a 10° curve the original 3-4 inch play is not exhausted. Inasmuch as wheels on a curve do not run freely as on tangents, but are always pressed against one rail, it is permissible to adopt the following rule based on the results given in the table: Curves under 4° to be spiked true gauge; above that and under 7° one quarter inch wide; above that and under 10°, one half inch, and then widening a quarter of an inch to each 2 1-2 degrees.

Having described the materials which form the "Permanent Way" and its appurtenances, together with the tools by which these materials are worked, the remainder of the chapter will relate to the proper use of the same.

TRACKWORK.

While, of course, the general idea governing all work should be the steady improvement of track, the immediate principle of details is that the work of one season should be devoted to the preparation for the next.

During the winter, when not engaged in handling snow, everything possible should be done to ease the rush of work in the busy time of spring and summer, and the most important of this preparatory work is getting the ties ready. This should be thought of and done early in the season, and the ties loaded, sent out and distributed along the track in places where they will be needed later, so that every tie will be on

the ground before the season opens. By beginning early, this work can be carried on at convenient times, and during a part of the year when traffic is usually light, and thereby unnecessary expense avoided. Labor can be spared in the winter better than in the spring, when the gangs should be steadily employed in tieing up their track, which latter work when once begun should not be delayed by a short supply of material, or by consuming valuable time in unloading and distributing. When ties are thus distributed several months ahead, it is better for the sake of general appearance to pile up about thirty or forty together in square piles rather than to leave them scattered along the banks or choking up the ditches.

When frost leaves the ground and while the track is settling in place, and as soon as the shims put in during the winter are taken out, the fences (unless looked after by a special gang, as should be done,) must be looked over and repaired; then the bad ditches cleared of obstructions to make place for the spring rains; followed by a rapid cleaning up of the section, after which the labor of putting in the ties begins. Once started this should be prosecuted with as much vigor and steadiness as possible. The best time for putting in ties is the spring, when the days are cool, men fresh and the ground soft and not baked by the sun. Since at this time more can be accomplished with each day's labor, a temporary increase of force will be found economical. If possible, track should be entirely tied up before grassing begins, which operation, consisting of mowing the right of way, cleaning the ditches and grubbing the track, should be done before the weeds go to seed. If the ballast is poor it may be necessary to grub the track three times or even more, if a neat appearance is desired, while with gravel, once or twice, according to its freedom from soil; and with broken stone, provided it is of full depth, not at all. The rest of the season can then be devoted to surfacing, lining and getting the track ready for winter.

Inasmuch as it is not advisable to stir up track just before winter, it should not be touched except for low joints or necessary repairs, during the four weeks preceding frost. This time should be devoted to building fence, weeding track, and good generous ditching. Culverts and bridge openings should be examined and cleared of all drift-trash and obstructions. All rails and material likely to be needed should be placed on skids, so as not to be lost in the snow, and planks at farm crossings should be taken up, since they cause uneven heaving.

During the winter the principal occupation (in northern climates) will be removal of snow, shimming track, (unless the ballast is so good as not to heave) and keeping switches, frogs, guard rails, etc., free from ice, while the frogs and rails themselves will be found to need more attention and more frequent changing on account of the inelastic condition of the road-bed. At other times the force can be economically employed in gauging track, tightening up and replacing bolts, and getting the ties and fence posts ready for the coming spring. The above is a sketch of the distribution of the work throughout the year.

No work can be successful unless prosecuted in a systematic manner, so there must exist in the mind of the Roadmaster or Engineer a definite preconceived plan of procedure, according to which he must marshal his forces as a general does his army, and the smaller the force at command, or the greater the obstacles to be overcome, the more necessity is there for good judgment on the part of the leader.

Track is brought up to a high degree of excellence only by hard, continued, patient work. One of the fundamental principles is to keep the whole track close to an even average, for nothing is gained by spending a large portion of the time in bringing certain spots to an extra degree of condition at the cost of neglect of others equally important. Therefore the Roadmaster or officer in charge should determine on a standard of excellence, by which to regulate the track during the season, and then always keeping men at work on that piece which is worst, and as soon as this piece reaches the standard—for nothing is gained by exceeding it—set them at that which is next worst, and so on until the whole is raised equally. Then next season raise the whole again to a still higher standard, till finally the desired perfect track is reached.

Of the work of track repairs in detail the principal item is the putting in of ties, and as such is worthy of particular attention. Ties of course should be kept in the track to the full extent of their utility, which means as long as they are sufficiently sound to afford a firm support for the rail, and to securely hold the spike. When they are no longer able properly to do this, although perhaps not so rotten as to be dangerous, it is very expensive to retain them in the track on account of the rail becoming permanently bent, and the continual work in gauging and surfacing necessary to keep the track in line and surface. The first and great principle to be observed is to afford a continuous amount of elasticity in the rail support, which cannot be too strongly insisted upon. The waves of depression should be evenly transmitted, and broken as little as possible, for wherever it is broken an injurious vibration is set up. Thus, if among old ties occasional new and sound ones are interspersed, the old ties crushing easily under the weight of the train give a greater undulation than would be due to the elasticity of the ballast in sound ties, which undulation is checked on reaching the new tie, and this action soon shakes the latter loose. In order to provide a uniform elasticity, ties should be assorted so as to afford similar bearing, that is, be put together according as they are large or small, hard or soft, and of greater or less durability, in order that the value of their service and length of life should be the same. It is therefore advisable to "tie up out of face," so that the support of the rail shall not be a succession of hard and soft spots. In addition to this reason it is better to "tie up out of face," and at the same time use durable ties, in order that the road-bed shall be allowed to settle and pack firmly and except at long intervals only disturbed for occasional small surfacing as needed; furthermore, track can be more quickly and economically tied up this way than by patch work.

With old established roads, this practice is frequently objected to on the plea that it may waste part of the life of the tie; but this objection is met by putting into sidings any half-worn ties that are taken out, where their term of life will repay the labor; or even by putting them in some other part of the track in company with ties of a similar character, to replace some occasional completely rotted ones, and so reap the advantage of not only saving a year or two's lease of life, but also by repairing such part better than would be done by introducing a new tie, and allowing it in turn to be retied wholesale, when the original ties have become unfit for further use. This method will be found to work to the advantage of the track and will be economical in the expense of the labor of surfacing, for old and new ties, or ties differing in quality can be kept in surface only by constant work, whereas track, tied out of face with similar ties, will run for years with little attention.

There are two ways of working track when ties are put in; one is to tamp it care-

fully and bring it to a perfect surface, the other to give it a fair surface with less attention. By the latter method ties are put in faster, and by the former track is left in better shape; but the method to pursue depends on the conditions of the case. If the track is that of a first-class main line, it will be necessary to spend more time, tamp carefully and bring the rails to good alignment and surface, while if the road is of minor importance, where the track is not in good condition, it is best, unless there are very few ties needed, to hurry them in and then go over the whole track again with careful work. An attempt in such case to show good results early will end in patches of good and bad, and perhaps when the season is ended, all the ties will not be in. For track between two such extremes, good judgment must be the guide, and in deciding regard must be had to the condition of the track and the number of ties needed. In general, ties should be put in the track as rapidly and early as possible.

As to actual labor in doing the work, the first step is to distribute the ties where they will be needed, then if the ballast is sloped away from the rail as was recommended, the work is easy, although it must be performed with passage at all times safe for trains. With sloped ballast all the digging that is necessary is between those ties to be replaced so that they can be drawn out easily, while if material is packed up around the ends of ties, it must be removed in addition. Having done the necessary digging, start up the spikes for a rail length pulling entirely one-half of them, then block up the rail with a spike or bit of gravel, draw out three or four ties, smooth off the bed, put in new ones, half spike them and then proceed to remove the remainder. Always keep the track safely spiked and full spike it as soon as possible. The spikers should be provided with a small stick cut to the length of the projection of the tie beyond the base of rail, and every tie should be gauged by this stick before being fastened. Spikers should also see that no ballast or other obstruction is between the rail and tie, and that the former bears true on the latter, and if it does not, then the rough surface of the tie should be adzed even. If the track is to be newly ballasted and raised at the same time, before changing the ties, the track should first be lifted and ballast packed under the tie-ends sufficient to hold the track in place, after which the ties can be easily drawn out and replaced without digging or hard pulling. After the ties are changed fill in and complete the raising. If weather promises fair, men can be allowed to work for two or three days simply changing, and then return to fill in and surface, for this will give a longer stretch to sight over, and a better chance of getting it done correctly, besides expediting the work. If, however, bad weather is probable, it is better to close at night each day's work. At the end of the day the old ties should be gathered together and placed in piles and removed from the right of way or burned. Nothing is more unsightly than to see the road-bed and ditches encumbered with old rotten ties, and the traveling public is too apt to draw the inference that they are but samples of many more still in use, for unfortunately the patrons of our roads have, as a rule, but a faint conception of the work performed and how the vast amount of property in the hands of maintenance of way men is taken care of. When putting in ties the ability of a foreman to properly handle and dispose of his gang is soon shown. He should so distribute his force that the men are far enough apart not to be in each other's way and yet be close enough for him to watch and control. With gravel ballast, each man in a gang should average, including surfacing, from twelve to sixteen ties per day's labor according to the facilities of the location for their removal.

It should also be remembered that ballast suffers by use as well as other material and finally packs so hard as to lose its elasticity; it should be removed from time to time. The best way to do this is to work at it continually rather than to handle it at intervals, which makes it more costly. If new ballast is distributed in small quantities each year, it should be done if possible in conjunction with changing ties, so that the one tamping will answer for both and leave the track in a condition to run, with the exception of small repairs, until the next re-tieing.

It is one thing to bring track to good surface and another to have it remain so; but the secret of permanence is tamping, for without this it will not stay.

Ties should be tamped their whole length and all should be tamped alike, except frog and joint ties which require harder work. Although the operation of tamping with the bar is slow, yet its use should be insisted on as economical in the end and the shovel allowed only in rough surfacing or temporary work. From the end of the tie to about one foot inside the rail the ballast should be packed hard and solidly, the tampers working in pairs so as to strike both sides at the same time and keep the material from being driven out from under. The ballast between these points, that is in the center of the tie, can be packed less hard, and for this the shovel may be permitted. If the center is tamped too hard, the tie will be supported there when the ballast settles under the rail and is liable to be broken, while on the other hand, if the center is not sufficiently tamped, it makes a sort of blind drain, into which the surface water runs and softens all the rest of the work. No matter how hard new ballast is tamped, it will settle, and to allow for this, track being raised should be put from 1-4 to 1 inch high according to the amount of the lift, and newly raised joints should crown from 1-8 in. to 1-4 in. for the same reason. If the raise is considerable or track new, it is just as well with first surfacing to tamp with shovels, because it will settle no matter how carefully done; then after trains have packed it down so that settling has ceased, go over it again with bars, and work will then be permanent.

Track foremen when at work should notice the effect of all passing trains, and especially their action upon the joints. Track well-tamped will deflect but little, and that little will be uniform, while poorly tamped track, although in good surface immediately before and after the passage of a train, will yield during that time considerably and unevenly; this action materially assists the rail to cut into the ties and the spikes to work up and get loose.

Ties beyond the joints should be watched, because the loosening of these ties has a damaging effect on the splice-bars, as previously explained.

Before winter, it is well, in yards, to tamp frog-ties and head-blocks (if stub-switches are used) to prevent water settling under them, although it is not advisable, as a rule, to disturb the solidity of the road-bed just previous to frost.

It is for every reason best when raising or lining track, to do so with aid of an instrument, provided the quantity of work extends beyond ordinary small repairs. Thus for alignment set plugs, making the track center every fifty feet to one hundred feet, as was mentioned above; and for surface, grade stakes at about the same distance, the stakes giving the level to which the top of the rail is to be raised. On tangents they can be set on the most convenient side of the track, but on curves they should be next to the inner rail, so that foreman can adjust the track opposite each stake with

his spirit-level, and then raise the intermediate portion by eye. By this setting of stakes the foreman is allowed to be with his men and not at a distance sighting along the rail; the men are kept continuously at work, and are not obliged to wait at intervals for him to gauge the proper elevation by his eye; and above all the work is not only performed quicker but more accurately.

In case an engineer cannot be had to give grade stakes, each foreman can make a level board for himself, which will give better results than his eye alone. Let him take a board five feet to six feet long by twelve inches wide, paint it with three longitudinal stripes, each four inches wide, the lower and upper ones black and the center one white. Then get two blocks about 6 in. × 6 in. × 6 in., cutting a groove down the center two inches deep, and as wide as the rail-head so that they will set over the rail like a saddle and be just four inches above it. The striped board is placed across the track at one end of the piece to be raised, and propped up, the track having first been levelled transversely. The foreman then retires to the other end of the stretch, setting one of the blocks on top of the rail by him, while the other block is placed at successive intervals between him and the level board. Then he sights over the top of the first block at the bottom of the white stripe and directs the track to be raised until the top of the intermediate block just touches the line of sight. That gives one point to grade, and similar repetitions raise the whole sag to where it should be. The two rails are then adjusted transversely by means of a spirit-level.

With curves the inside rail should be levelled first and then the outside rail raised above it according to the proper elevation. Some trackmen reverse this rule and raise the outer rail first, but in no case can they gain by so doing and they can readily lose, if they do not happen (for it is a case of happen) to get the outer rail correct at the start. Such a proceeding is putting the cart before the horse, as the inside rail is "grade," while the outside rail is to be raised higher. If the outside rail is very low then the inside rail should not be raised quite to grade, remembering that when the outside is raised later, it will bring the inside rail up too, since the ties are like levers with a bearing on one end. Again, if the outside rail is very irregular, the proper allowance for that must accordingly be made, or else bring the whole curve to a fair surface before finishing. If the raise is to be considerable it may be necessary to do it with two or more lifts, depending on the frequency of trains.

On double track it is better to raise against the direction of traffic, as it is safer and easier to have trains ascend than descend the temporary steep incline.

SHIMS.

In winter when the ground is frozen, the ballast, unless perfectly porous, is unequally heaved by frost. Since it is then impossible to tamp, recourse must be had to shimming low spots, as the putting of blocks under the rail is called, or in extreme cases adzing down the ties under the high places. This latter alternative should be resorted to only as a last resort, when it is impossible to block upon the adjoining ties to correspond, as a tie once adzed is ruined and must be replaced next season, even if it is not troublesome during the winter.

Shims can be manufactured in the shops and sent out, or else made by the trackmen as needed. In the latter case they take a straight grained hard wood tie (oak preferred), saw it into blocks about 8 inches to 10 inches long, and split these with a hand axe into pieces of such thickness as required. When they are manufactured

in the shops, strips of any convenient hardwood, 6 inches wide and in thickness varying from 1-8 inch to 1 1-2 inch are sawed into pieces 10 inches long, and then drilled according to template with two 1-inch holes, such holes being set diagonally opposite each other according to Fig. 119, where the dotted lines show the edges of the rail base.

Unless the split shims are hand-drilled for a spike hole, they must be placed under the rail diagonally between the spikes, since to spike through them would break them. The advantages of sawed shims are cheapness, since any wood may be used, whereas only the best of ties can be split; better bearing; greater security against slipping out of place; and the thicker shims can be used again. Shims used on bridge ties should always be machine made. No shim thicker than 2 inches should ever be used, and in case track heaves so badly as to require more, a piece of plank should be spiked to the tie and shims put on that in the usual manner; in fact when blocking gets over 1 inch high, side braces should be spiked against the rail.

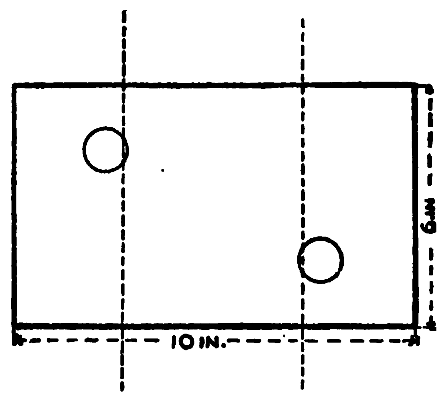


FIG. 119 —SAWED SHIM.

This practice of blocking underneath ties should be forbidden except in very bad cases, because it is better to let the tie rest in the same bed it has made, and because there is danger that the blocks may be left in when spring comes.

If track is laid in clay it will heave very badly; in extreme cases I have seen ties raise 20 inches from their bed, with the track supported entirely in the center. In such an event the only remedy to prevent ties from breaking and keep the track safe, is to block up underneath with plank and gradually remove the latter as the track settles. Sometimes in spring when the frost is coming out, ties in mud ballast will abruptly settle in spots to the extent of several inches. The best thing for a temporary job is to block up underneath with plank, fence boards, or anything handy, then dig out the wet mud and replace it with fresh cinders, which seem to act like a sponge and are superior to gravel for such work.

As soon as the frost leaves the ground, all shims should be taken out, and those which can be used again piled up for the next winter, and low ties tamped up to a good bearing. Winters when snow is permanent are better for track than those without it, and steady cold is less severe than alternate spells of thaw and freeze. As frost comes out, track needs most attention, as it will frequently, if the ballast be poor, rise or sink considerably in a few hours, and this weather is also most trying on rails as they are then apt to break either from physical changes in the metal itself or from the uneven support they receive.

DITCHING.

On the majority of roads the questions of drainage and ditching do not receive adequate attention, but their importance should be diligently impressed on the minds of every one. In yards the best plan is porous ballast, and if there are places where water collects, wells covered with a grating should be sunk and either connected with

a sewer or else dug deep enough below frost line to act as a cesspool. Into these wells surface drains can be led. Outside of the yard the regular side ditches should be constructed as previously illustrated in the cross-section diagrams. Some pains should be taken on the part of the foreman to see that the men cut the ditch true, its back edge straight, sloped from the tie ends uniformly, and bottom even, leaving no pools or ridges which will hold water. It requires no more time, but only more care to make a ditch properly than improperly.

HANDLING RAILS.

As a rule rails are not handled carefully enough. Abroad, where rails are bought under close contracts, it is expressly stipulated that they shall not be unloaded except by skids. In this country they are too often thrown off the cars into piles, bending or injuring many. Before laying, such bends should be straightened by a rail bender. When old track is repaired with new steel rails, the road-bed should be surfaced and rotten ties replaced before doing so. Rails represent a large sum of money, and the permanent damage done to them by laying them on a poor foundation can soon amount to one quarter of the original outlay. In case ties are cut and cannot be changed, they should be adzed to give the rail an even bearing. But if new steel is introduced for ordinary repairs it is better to lay the new steel all together and use that which is taken out for patching, so that rails of the same height are kept by themselves. In laying rail, ample allowance should be made for expansion. A 30-foot rail will expand 1-4 inch with a change of 100° Fahrenheit. In case steel has to be cut, the bolt holes must be drilled; iron may be punched but steel cannot, as it destroys its tenacity. When a cut rail is used, the full complement of bolt holes should be put in so as to make the joints secure.

It is not every man who can drive a spike properly. Spikes should be driven straight and snug up against the rail base, and this should be obtained naturally and not by a last blow on the side of the spike head so as to bend it over against the rail and give it the appearance of a fit. As a guide on starting, the lip of a spike should be placed against the side of the rail head, and then with straight blows the spike will be driven properly.

Unless bolts are kept tight joints will not stay up. When rails, splices and bolts are new, the latter will need retightening shortly after their first setting, that is, when the scale is knocked off and the bearing surfaces have worked to fit. With old track the gang should go over the track at least every spring and autumn and give all the bolts a general overhauling, and between these times the track walker can take care of them.

Track on bridges and approaches should be maintained in the best possible condition, the alignment especially being kept perfect. At each end of a bridge the track should be most carefully tamped so as to have as nearly as can be the same spring or elasticity as the bridge itself. It is very damaging to the bridge to have a train drop on it as it were, from higher track, or to strike it by its being raised above the approach. If a bridge is on a curve, the outside rail must be elevated precisely the same as the rest of the curve, while, if it is at a point of curvature (something to to be avoided in location) the elevation must be run out according to the rule previously given by means of graduated shims, which shims should be substantial affairs nailed to the floor beams or ties. In other words every care should be taken to have trains pass on and off without jar, as such jar is very detrimental to the structure. A neat and quick way to line track on a bridge is to determine at both ends, and in-

termediate points also if the bridge is long, where the outer edge of one rail flange is to be; between these points snap a chalk line and then the rail can be spiked so that the edge of the flange just cuts this line, after which the other rail can be laid to gauge.

GRASSING.

Grass is the most annoying matter that trackmen have to deal with; it is so energetic and thrifty, that no matter how hard it is fought it persists in growing and marring the appearance of the track. The operation of grassing consists of mowing the right of way and grubbing the track and road-bed. How often that is necessary depends upon the productive qualities of the soil, and the degree of neat appearance required. If perfection is demanded, it is necessary to mow the right of way twice, and grub the ditches constantly, and from this standard, practice can be toned down to meet the wants of the lowest limit, which is that grass shall not grow so high as to get between the wheels and rails so as to cause slipping. Mowing should be done as late as possible in early summer, so as to make one mowing answer, and just before the weeds are ready to seed down. After mowing, the weeds and grass should be raked together and either removed or burned, for if they are left to dry they are sure to catch fire and carry it to the fence. At the same time that the mowing is done the road-bed should be grubbed of its weeds and small grass, then, unless the ballast is full of loam, so as to raise a second crop at once, the next grubbing can be postponed until autumn when the right of way can be mowed if necessary. In cleaning the road-bed out beyond the ends of the ties, the work should be carried to a straight edge to conform with the standard cross-section. Mowing is done with different scythes as previously described, and over ordinary ground and on a right of way 66 feet to 100 feet wide, a foreman and six men can mow about one mile per day. Grubbing is done with shovels or grub hoes, and the same force can clean from one-quarter mile to one mile of track per day, according to the heaviness of the growth.

To some this cleaning of the roadway appears unnecessary and costly as being for appearance only, and taking time which might be devoted to repairs of track. But there are in its favor practical as well as esthetical reasons. When the grass, weeds and bushes are allowed to grow high, they afford a cover for cattle, and prevent them from being seen until they actually step out in front of a train; when this same brush withers and dies under the August sun, it provides copious material for an extensive fire. While on no account is good work to be sacrificed for appearance only, by devoting to the latter too great a share of time, still a certain amount of attention must be paid to it, because a slovenly exterior is sure to give a road a poor reputation, on the principle that we are all too apt to judge a man by the coat he wears; the ordinary layman standing on a station platform or looking out of a car window, and seeing the grass nicely cut, ties in line and the whole right of way in neat and trim order, will be impressed with the idea that the road-bed is in excellent condition, and ride along with the firm belief that the track is perfectly smooth. A railroad man having to deal with large numbers of people should be ever watchful and ready to turn to his advantage their weaknesses, and so oftentimes be enabled to produce a desired impression by giving a pleasing effect to the eye.

SNOW.

A northern climate's snow is the greatest enemy of the trackman, and how to handle it is what every one wants to know. In some localities business must be suspended until the storm is past, while in others less severe, the obstructive material is

attacked with various kinds of ploughs, and to enter into a description of these "outfits" is hardly possible, as each locality requires a different treatment, so we will only give a few words to the question in general. The first principle to be observed is to keep ahead of the snow if possible, that is, not to permit the snow to drift and pack and so close the line. This is best done by running ploughs constantly over the track, or else engines with their pilots sheathed, if the regular trains are not close enough together. As soon as a storm is over, men should get to work and clear those places offering the most resistance. If the snow is deep, a plough should run over the line followed by a "flanging car" (to be hereafter described), or if the fall is light and does not exceed one and a half to two feet, the plough can be dispensed with, provided the engine drawing the flanging car has a plough attachment in place of the pilot. This will soon put the main track in good shape. In the meantime track gangs, augmented if necessary, should clean the switches and frogs first, and then the sidings in the order of their importance. In case a flanging car is not used, the track must be flanged, that is, the snow removed next to the inside of the rails, by hand, and this should follow, (unless the force is large enough to do all simultaneously) the cleaning of the switches, frogs and principal sidings. If the snow is deep it is a long and tedious job to flange with the shovel, as one man can cover scarcely 1-2 mile of track per day at best, while the machine can run 15 miles per hour. It is a bad plan to depend on a thaw to remove snow; much better to make sure, and as soon as the track is in running condition to load on cars and remove all snow from yards, narrow cuts and wherever it may be an obstruction, and so be ready for the next storm. When cleaning a switch, the snow should be entirely removed around the switch apparatus and thence to the heel of the frog, cleaning out the channels of the latter and the space between the guard rail and the main rail. Between crossing or platform planks and the rail snow soon packs hard and freezes into ice, so as to require slow and tedious picking to cut it out. This can be obviated by sprinkling salt, which will keep the snow soft, or will soften it until such time as it can be removed. One barrel of salt will save much manual labor and wear of picks.

A flanging car is a machine to mechanically remove snow from the inside of both rails; there are several different designs, but the accompanying diagrams of the standard of N. Y., W-S. & B. R. R., (pages 108, 109) show an improved type in detail. Fig. 120 gives a side elevation of the car and flanger, while Fig. 121 is an end elevation with additional details; in Fig. 122 the flanger is seen in inverted plan. The

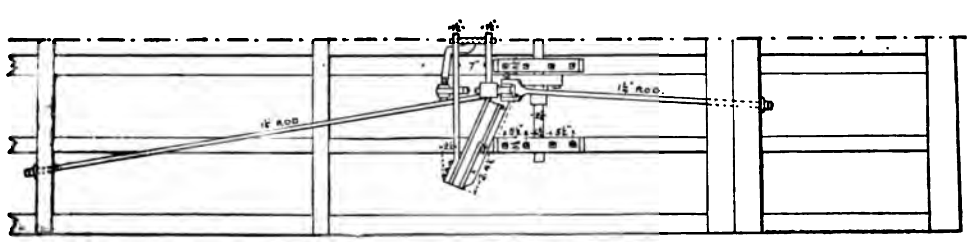


FIG. 122.—THE FLANGER IN INVERTED PLAN.

apparatus can be attached to a box-car or even to a flat car housed over to protect the attendants from the weather. On approaching frogs, crossings, etc., the flanger must be raised, and the pressure of such obstructions and their consequent passage can be denoted by a series of signals from the engine which hauls the car. But even if the flanger should strike such an obstacle, damage will not result unless running at a high

rate of spe͜ed as the blow will simply throw the flanger up. The car as designed intends the hoisting to be done by block and fall as indicated in Fig 120. It is much better to use compressed air from the air-brake apparatus. The method of attaching the cylinder is shown in Fig. 120, where it is hung on a pin to the roof timbers, so as to revolve as the lever is raised. The best position for the cylinder is a mean inclination between the normals to the lever when down or raised. Fig. 123 (page 110) gives full details of the cylinder, which, as will be seen, is single headed, air on one side only being needed. The method of connecting the supply and exhaust and working the apparatus by the two stop-cocks, together with the other features, are clearly shown in the cuts. Such a car is a great saving in labor and is of incomparable assistance to the transportation department.

Every officer of Maintenance of Way should at all times endeavor to inspire each foreman with an *esprit de corps* and institute between the different men a friendly rivalry, to which end will be found conducive a well regulated system of rewards and the practice of periodically publishing the amount of work performed on the various sections, as for instance, ties replaced, taking care, however, that the quality of the work is not slighted for the sake of speed. First, establish an air of neatness about everything. Whatever work the men are at, make them do it in a cleanly manner, which costs little and kindles a feeling of pride. Make the men begin with their tool houses, insist that they shall be kept clean and orderly, and that every tool and supply shall have its proper place, pegs to hang shovels on, racks to support the mauls, picks and tools, a definite corner for the bars, the extra bolts and spikes in kegs and not loose so that in the morning when starting out fifteen minutes need not be lost looking for some special article.

Outside the house there should be a platform divided into three partitions for car scraps, wrought, and cast track scrap, so that when any particular kind is to be shipped it is already sorted. Extra fence material, crossing plank, splice bars and such supplies, should be laid up in neat piles. Be very particular with the men as to the policing of their sections. Regular skids should be made at stated intervals to hold the extra rails, and then rails should be placed on the skids parallel to the main track, and not simply thrown down. Whenever draw-bars, car doors and scrap of any kind is seen lying by the track, it should be at once picked up, and either placed in its proper pile at the tool-house, or shipped away according to instructions. Then on regular occasions, not less than once a month, a systematic cleaning of the section should be made, picking up bolts, spikes and other small pieces which are not seen, as the men run their hand car to and fro. The value of scrap lying along the road is considerable, and is worth attention; besides it impresses on the mind of the men their responsibility of trust of the company's property, and that they must take care of it. The track and grounds around stations and yards should be kept especially clean, for here it is that the roadbed is most seen, and therefore should always be in holiday attire.

Every foreman should be made to understand the motto, "Do to-day.'

Work should not needlessly be postponed, and no job should be undertaken unless with reasonable prospect of completing it without interruption.

A foreman should not only make every day's work count, but endeavor to finish it in a substantial manner, so as not to require returning to it later. It seems tempt-

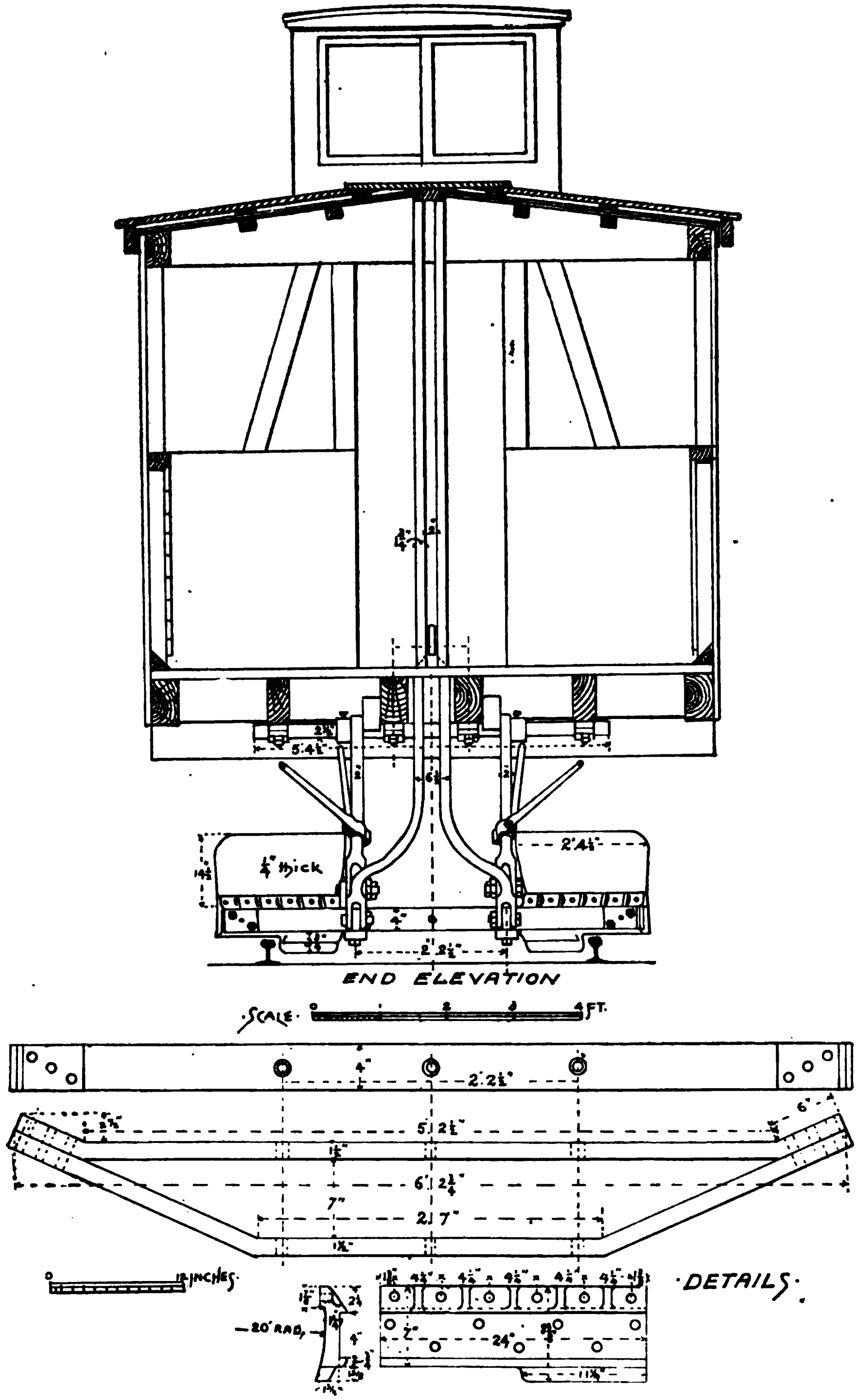


FIG. 120.—FLANGING CAR: END ELEVATION AND DETAILS.

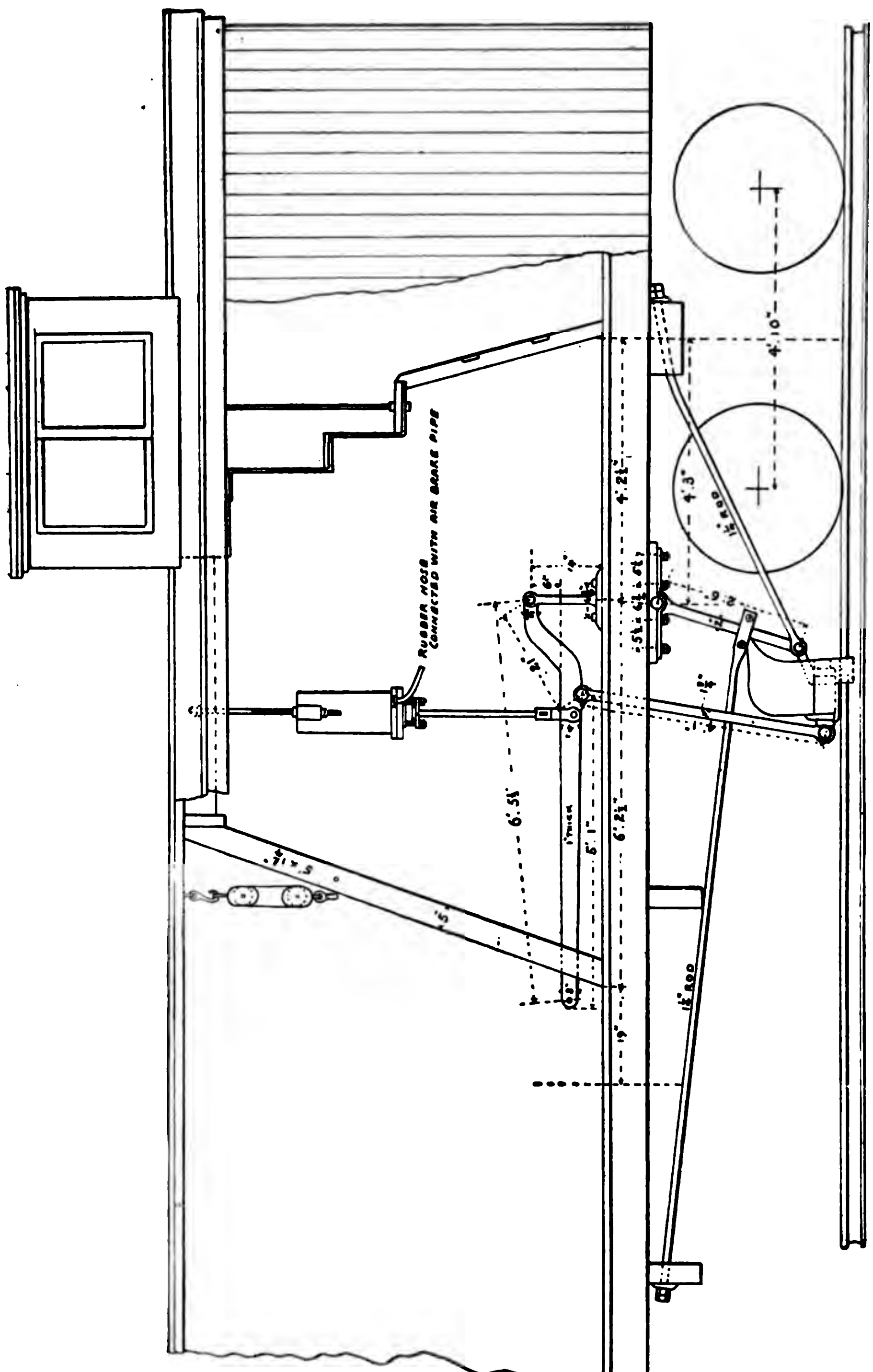
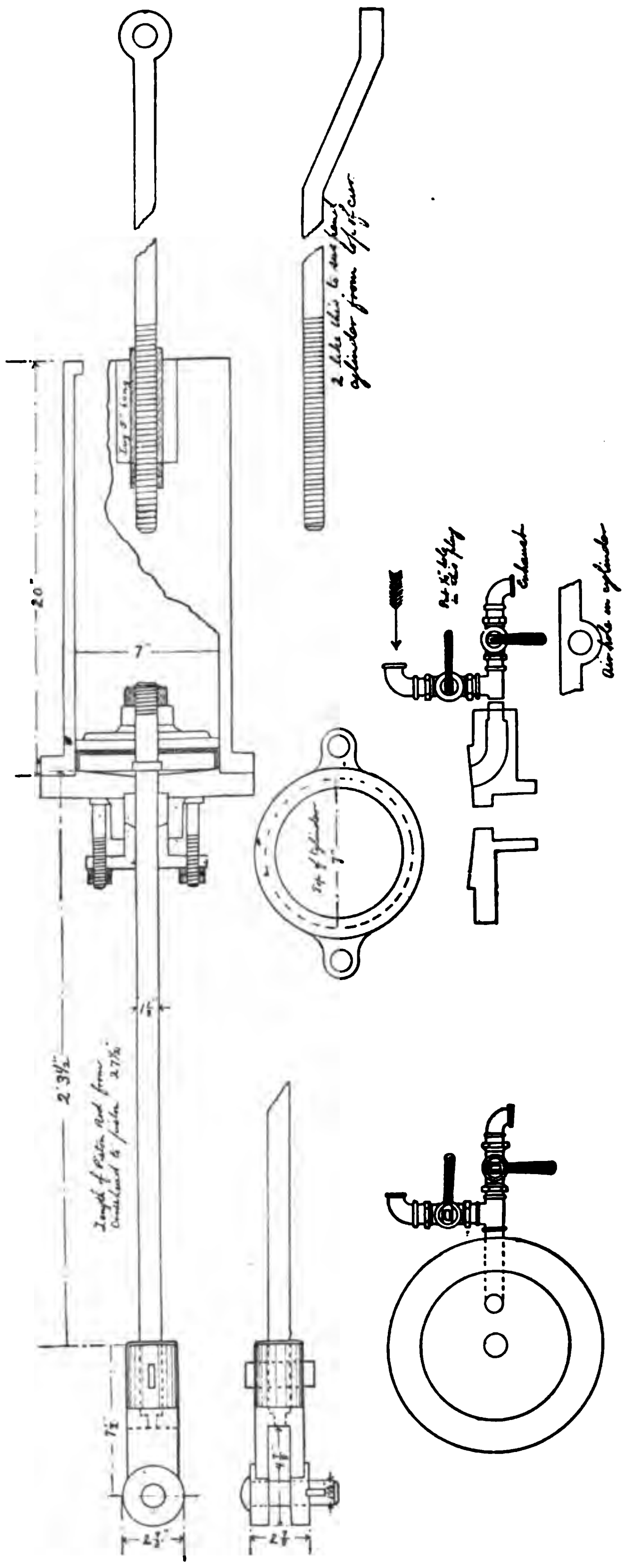


Fig. 121.—Flanging Car, N. Y., W. S. & B. R. R.: Side Elevation.



ing for him, no doubt, to tamp slightly, or to hurry the dressing off in order to work over more track than his neighbors; but a job well done is finished, it needs no tinkering afterwards, and although it takes a little longer in the first place, do not let the men be discharged, as it will pay in the end.

The ability of a foreman to exercise a proper and firm control over his men, to distribute the force to the best advantage while at work, should be considered quite as much as his judgment or his own working abilities.

The first can only be discovered, unless the lack is very flagrant, by close watching, but the second can readily be seen every time the gang is passed. The foreman who does not understand will have all his men in a heap, so that they are in each other's way, and unless stopped, men will take such positions as best gives them a chance to "old soldier."

Men should be far enough apart to be able to work easily, and so arranged, if possible, that each man has but one bit of work to accomplish by himself, so that the laggard is easily detected. This can best be illustrated by such operations as cutting grass or flanging

FIG. 122.—FLANGING CAR, DETAILS OF HOISTING ATTACHMENT.

out snow, where, if the men cannot all work abreast on separate tracks, they should be set to trail at the space of one or two telegraph poles apart, and then the whole force should moves ahead bodily, and the individuals not be allowed to walk around each other to get a fresh spot. A poor foreman will let his men follow close upon each other's heels so that they really work over the same ground, each man skimming a little deeper than his leader.

For the purpose of estimating or judging the capabilities of a given force every officer should acquaint himself with the amount of work one man in a well organized gang can accomplish in a day of ten hours. The following table gives an approximate value of the day's labor for various important items under ordinary average conditions, the material in each case supposed to be conveniently distributed beforehand as in actual practice:

Cinders, loading	25 cu. yds.
Fence, building—board	80 feet
" " —wire	195 "
Gravel, loading	12 to 15 cu. yds.
Grubbing road-bed	300 to 900 feet
Mowing right of way	1 acre
Rails, replacing (no trains)	200 feet
Snow, flanging	2,000 ft. track
Ties, making, including felling, sawing, hewing	20
" loading from road-bed level	200
" " " platform	300
" replacing	14
" tamping, with bars	40
" " " shovels	120
Track laying	300 feet
" laying and surfacing	100 "
" raising 6 inches, shovel tamping	150 "
" surfacing very carefully with bars	40 "
Car load of gravel loaded by steam shovel	6 cu. yds.
" " " " hand	8 to 10 "

A foreman should watch and study everything about his work so as to know the cause which leads to every result. If some part is wrong and keeps on getting so each time after repairing, the question "why" should be asked, so as to try and find the cause, and remove that, for prevention is better than cure. Thus if a curve keeps always working out of line, it should not be blamed on the engines, and a part of every day's work spent in throwing the track back, but the origin of the trouble should be discovered. Perhaps the curve is too low, or the joints are opposite. Again, if the side of a frog point wears excessively, it should not simply be condemned and sent to the shop, but the cause of the wear should be found out, which probably will be that the guard rail is too loose. So, if the outside rail of a curve shows heavy wear, it means that the elevation is insufficient. These are simple every day samples which serve to show the meaning, and although the large majority of our track foremen work on just this principle, yet there is many a good, faithful man who does not get on in spite of his abilities to work, but who could be made a most useful leader if properly taught to use his intellectual faculties.

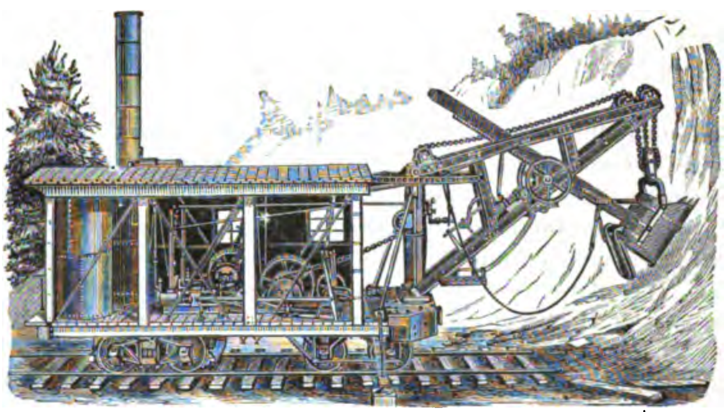
FINIS.

STEAM EXCAVATORS.

In modern railway construction the steam shovel has come to be recognized as an important factor. Heavy fills are now generally bridged over on piles in a temporary way, and the track once down, then the engine, cars, ballast unloader, and steam shovel all properly manned, serve to do the work of many teams and laborers, at much less cost per cubic yard and much less annoyance.

Also in ballasting the track, the steam shovel and the unloader, and a train, accomplish a great part of the work in a way that is so certain and satisfactory, that all other means are now about discarded.

In the use of these machines, the cost per cubic yard for handling all classes of materials except rock and solid shales, has been very much reduced. If any other



THE "THOMPSON" STEAM SHOVEL.

recommendation is needful, it is certainly found in the positive performance of these machines. They greatly reduce the number of men and teams necessary on such works, and thereby lessen the difficulties to be encountered in handling a body of laborers.

These machines work effectively even in very hard material, such as blue clay, cemented gravel, hard pan of moderate thickness, and loose shales; small fragmentary rocks are also handled in a very satisfactory way.

The machines are constructed on the M. C. B. Standard, and can be run on their own trucks over any track in either passenger or freight trains.

The machine here illustrated is that known as the "Thompson Steam Shovel," and is manufactured at Bucyrus, Ohio. It is capable of excavating and loading on to cars, 40,000 cubic yards of material in one day of ten hours, and it will do this day after day at a merely nominal expense for repairs.

II.

In these machines the framework, body of car, and the crane are all made of steel channels and I-beams, and they are substantial and enduring. The machinery is simple and compact and its management is easily learned.

The thrusting engine on the crane is a new invention which enables the machine to dig farther in advance; closer in the corners; and deeper below the level of the track than others. The boiler is constructed with special reference to its work, and is highly satisfactory in performance.

The machinery possesses many novel features that serve to reduce the expense of operating and at the same time adds to the ease of manipulation and increase of capacity. The friction clutches are of improved design and respond very promptly under the hand of the operator. The shafts and pinions are all made of steel. The parts are made interchangable, and duplicated pieces can be adjusted at once, causing very little stoppage on account of repairs.

This shovel is so constructed that it can be readily changed for use as a wrecking car, with a lifting capacity ranging from fifteen to twenty-five tons. The chains are made of wrought-iron and steel, and are fully tested. For transportation, the crane can be lowered without removal, in twenty minutes of time.

The merits of this particular shovel are attested by some of the leading railroads that have been using them a sufficient length of time to test their capacity. In one case the machine dug out four thousand yards every twenty-four hours. The shovel was found to be very easy to move, being self-propelling, and was economical in its working.

The cost of handling the four thousand yards, was, on an average, $58. as stated by Mr. D. M. Carey, Contractor of the Ohio River R. R. In another case, Mr. T. M. Peeler, Superintendent of the Ohio Central Railroad says, that even after the company had used a shovel constantly for three years, it was found to work rapidly in raising, swinging and dropping its dipper, while the delays from breakages were comparatively few. The shovel was used in all kinds of material and did excellent work. In one season, nine thousand cars of gravel were handled, an average of from one hundred to one hundred and twenty-five cars per day at ten yards per car, less than one half the shovel's full capacity. The average haul was forty-two miles, making a run of eighty-four miles. The trial test showed that the shovel will load twenty-five cars per hour. The expense of the shovel was from $15 to $20 per day, including help, fuel, etc.

These facts will be sufficient to show what a large amount of labor and expense is saved by using the excavator, especially when subjected to hard work with such satisfactory results as here given. The Thompson Shovel is made exclusively by the Bucyrus Foundry and Manufacturing Co., Bucyrus, Ohio.

THE GREAT SUCCESS!

GOLD MEDAL.

THE MONARCH RAILWAY TRACK-LAYER.

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We beg to call your attention to the **Best Track Laying Device** yet known and the ONLY ONE which received an award (gold medal) at the National Exposition of Railway Appliances, held in Chicago, 1883. It is simple, strong and durable. Its use does away entirely with ALL TEAM WORK in the distribution of ties and rails and leaves the road-bed as smooth as when graded, thus saving 50 to 75 per cent. of surfacing expenses. It enables the prosecution of work in wet weather, in muddy soil, where teams cannot be used, through sloughs, cuts and fills, over bridges and trestle work, through tunnels, mountains and uneven country, with the same facility and ease as on the smoothest road bed. It can be attached to any train of flat cars in ten minutes by two men, saving the expense and time of transferring or reloading material from one train to another.

All material is supplied to the track layers in the most rapid manner, and directly at the points required for immediate use—LEAVING NO SCATTERED MATERIAL.

☞ **CAPACITY OF TRACK-LAYER—ONE AND A HALF TO TWO MILES PER DAY.**

By our patent Track-Layer we MEAN to facilitate and lessen the time and expense of track laying. We let the machine on ROYALTY, sell ROAD RIGHTS or lay TRACK by CONTRACT.

Colored lithographic view and explanation of Track-Layer *sent free* on application. Correspondence solicited.

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